ENGINEERING STUDY FOR THE 200 AREA EFFLUENT TREATMENT FACILITY SECONDARY WASTE TREATMENT OF PROJECTED FUTURE WASTE FEEDS

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K. J Lueck
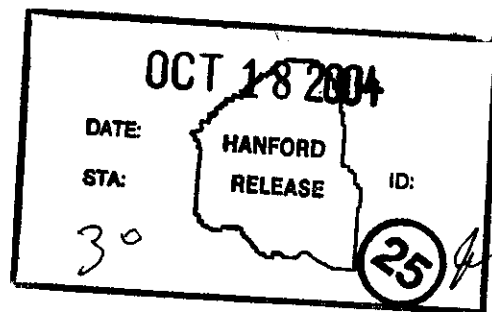
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Fluor Hanford

P.O. Box 1000
Richland, Washington

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May 14, 2004

Prepared For
Fluor Hanford, Inc.
Richland, Washington

Prepared By
Columbia Energy & Environmental Services, Inc.
Richland, Washington

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HNF-23142, Rev. 0

Engineering Study for the 200 Area Effluent Treatment Facility
Secondary Waste Treatment of Projected Future Waste Feeds

CEES-0105, Rev. 0

EXECUTIVE SUMMARY

This engineering study was conducted to evaluate alternatives to ensure the 200 Area Effluent Treatment Facility had sufficient capacity and produced a secondary waste product that would meet future disposal requirements. This report evaluates alternatives, accounting for projected influents to the 200 Area Effluent Treatment Facility, and future disposal requirements.

Nine alternatives were considered for producing the secondary treatment train waste product. Alternatives included process optimization, seven drying alternatives, and a stabilization alternative. A down-select of the seven drying alternatives was performed by evaluating each against the screening criteria. Three down-select drying alternatives and the stabilization alternative were then evaluated against 14 weighted evaluation criteria to define a preferred alternative. A flow chart of the evaluation process is shown in Figure ES.1.

Figure ES.1. Evaluation Process for 200 Area Effluent Treatment Facility Secondary Treatment Train Alternatives
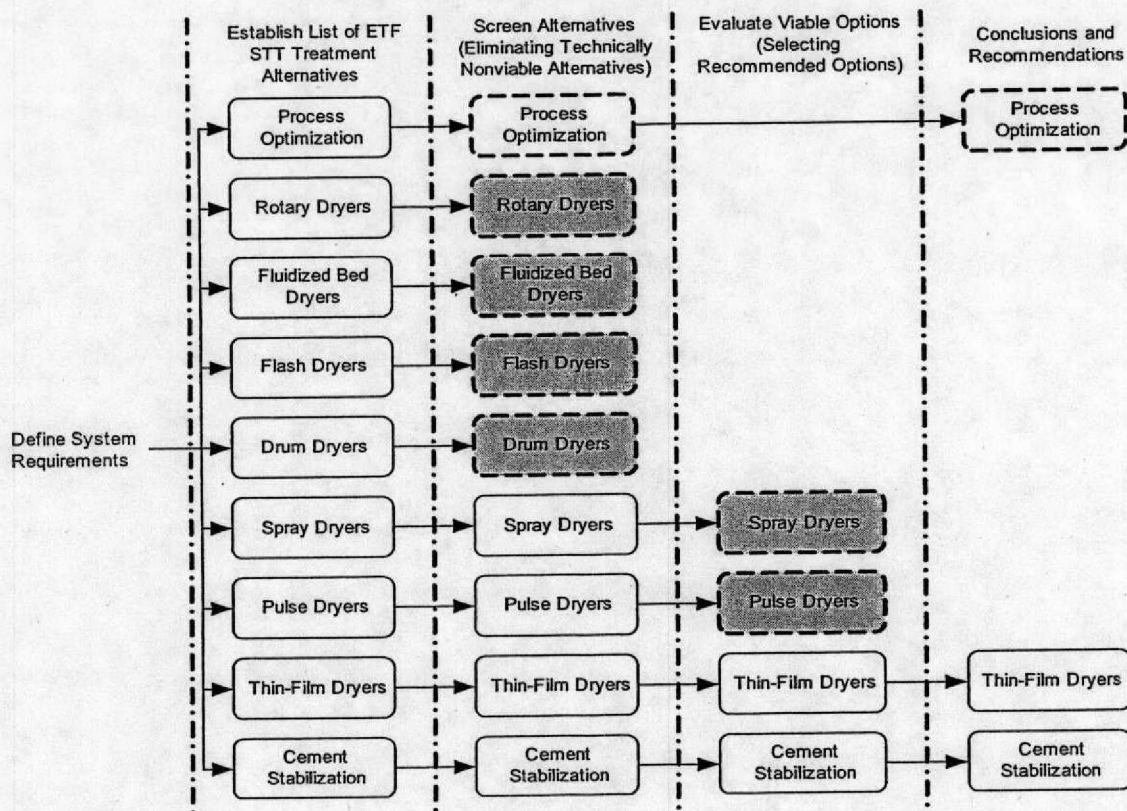
ETF = Effluent Treatment Facility.
STT = secondary treatment train.

Legend:

☐ Considered during evaluation phase.

┌ ─ ┐ Consider during evaluation phase but
└ ─ ┘ eliminated from further consideration in later phases.

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A drying alternative using a larger thin-film dryer that operates parallel with the current dryer would accommodate the increased capacity need for the secondary treatment train. However, because there may be issues with performance of the powder waste form at final disposal, the stabilization alternative is the preferred alternative because it can meet both the 200 Area Effluent Treatment Facility capacity needs and waste form issues. Additionally, the current forecast is preliminary and there is concern that treatment of the influent from the Waste Treatment Plant and Supplemental Treatment Facilities may generate a waste that is not Land Disposal Restrictions compliant, is above radiological Category 3, and/or contains mobile radionuclides, stabilization provides the flexibility to meet final disposal requirements.

The stabilization alternative is a cement-based stabilization, similar to cast stone. A stabilization system provides the additional flexibility of using different cement-based stabilization formulas to meet the final disposal waste acceptance criteria. Once the final disposal facility waste acceptance criteria have been defined, a tailored formulation can be selected if necessary. The rough order of magnitude cost for installation of a stabilized system is $1.1 million.

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LIST OF TERMS

ETF	200 Area Effluent Treatment Facility
STT	secondary treatment train
WTP	Waste Treatment Plant

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1.0 INTRODUCTION

This report documents an engineering study conducted to evaluate alternatives for treating secondary waste in the secondary treatment train (STT) of the Hanford Site 200 Area Effluent Treatment Facility (ETF). The study evaluates ETF STT treatment alternatives and recommends preferred alternatives for meeting the projected future missions of the ETF. The preferred alternative(s) will process projected future ETF influents to produce a solid waste acceptable for final disposal on the Hanford Site.

The main text of this report summarizes the ETF past and projected operations, lists the assumptions about projected operations that provide the basis for the engineering evaluation, and summarizes the evaluation process. The evaluation process includes identification of available modifications to the current ETF process, screens those modifications for technical viability, evaluates the technically viable alternatives, and provides conclusions and recommendations based on that evaluation.

Details of the evaluation process are provided in appendices to this report:

- **Appendix A** – Details on the projected ETF feed composition

- **Appendix B** – Details the available drying alternatives

- **Appendix C** – Details the screening process that identified the technically viable modifications

- **Appendix D** – Details the evaluation of the technically viable alternatives

- **Appendix E** – Provides the waste product performance requirements for the cast stone process.

2.0 SCOPE AND PURPOSE

The purpose of this study is to evaluate ETF STT treatment alternatives for maintaining the viability of ETF in treating the wastewaters generated as a result of the Hanford cleanup mission. The alternatives and subsequent evaluation address the projected ETF influent bounding case with respect to influent volumes and salt concentrations. For the purposes of this study, it is assumed that the projected ETF influents from the Waste Treatment Plant (WTP) and the supplemental low-level waste treatment process represent the bounding case as provided in Tables 1 and 2.

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Table 1. Projected ETF Influent and Brine Maximum and Minimum Yearly Average Ionic Concentration (2010-2028)

Isotopes	Average Influent (mg/L)	pH Adjusted Influent (mg/L)	Evaporator Brine (mg/L)	Evaporator Brine (Ionic wt%)	
Ca – min.	8.68E-03	8.68E-03	7.08E-02	0.00	of TDS
Ca – max.	4.73E-02	4.73E-02	1.62E-01	0.00	of TDS
Fe – min.	3.79E-03	3.79E-03	3.76E-02	0.00	of TDS
Fe – max.	1.62E-02	1.62E-02	1.48E-01	0.00	of TDS
Na – min.	5.67E+03	5.67E+03	5.07E+04	20.30	of TDS
Na – max.	8.54E+03	8.54E+03	5.66E+04	22.63	of TDS
Cl – min.	6.98E-01	6.98E-01	6.97E+00	0.00	of TDS
Cl – max.	4.00E+00	4.00E+00	3.26E+01	0.01	of TDS
CO_3 – min.	7.16E+03	3.58E+02	3.22E+03	1.29	of TDS
CO_3 – max.	1.09E+04	5.43E+02	3.57E+03	1.43	of TDS
F – min.	5.30E-02	5.30E-02	4.84E-01	0.00	of TDS
F – max.	3.09E-01	3.09E-01	2.52E+00	0.00	of TDS
NH_3 – min.	2.11E+03	2.11E+03	2.10E+04	8.42	of TDS
NH_3 – max.	4.37E+03	4.37E+03	2.59E+04	10.38	of TDS
NO_2 – min.	2.28E+00	2.28E+00	2.70E+01	0.01	of TDS
NO_2 – max.	5.69E+00	5.69E+00	5.02E+01	0.02	of TDS
NO_3 – min.	6.72E+01	6.72E+01	4.79E+02	0.19	of TDS
NO_3 – max.	9.44E+01	9.44E+01	8.31E+02	0.33	of TDS
PO_4 – min.	4.89E-01	4.89E-01	2.91E+00	0.00	of TDS
PO_4 – max.	3.17E+00	3.17E+00	1.47E+01	0.01	of TDS
SO_4 – min.	1.30E+00	1.68E+04	1.68E+05	67.15	of TDS
SO_4 – max.	5.86E+00	2.85E+04	1.70E+05	67.82	of TDS
TDS – min.	1.52E+04	2.50E+04	2.50E+05	100.00	of TDS
TDS – max.	2.41E+04	4.21E+04	2.50E+05	100.00	of TDS

Note: The evaporator brine is produced at 6.8 L/min (1.8 gal/min); this table shows the minimum and maximum concentration of key ions during the projected 2010-2028 production run.

TDS = total dissolved solids.

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**Table 2. Estimated Percentage of Crystals
Formed in the ETF Drying System**

Crystal	Wt%
$NaNO_3$	0.5
Na_2CO_3	2.5
Na_2SO_4	61.9
$(NH_4)_2SO_4$	35.1

Notes: (1) The salt concentration estimations in this table are based on a calculation to determine 98 wt% of the probable salts formed in the dryer using valance stochiometry, and selection between the ions by relative electronegativity.
(2) Na, NH_3, NO_3, CO_3 and SO_4 comprise 98 wt% of the ions in the projected ETF evaporator feed brine, based on a table of brine composition provided as Table A.2 in Appendix A and maximum ion composition provided in Table 1. The ions that constitute the remaining 2 wt% form salts that contribute <0.5 wt% to the total dissolved solids.
ETF = Effluent Treatment Facility.

3.0 BACKGROUND

The ETF receives, treats, and disposes of liquid effluents from cleanup projects on the Hanford Site. The ETF currently supports the 242-A Evaporator, Burial Grounds, Groundwater Treatment Projects, and other decontamination and decommissioning projects. The liquid effluents are treated to remove toxic metals, radionuclides, and ammonia; and to destroy organic compounds. The primary treatment train represents best available technology and includes the following processes:

- pH adjustment
- Filtration
- Ultraviolet light/peroxide destruction of organic compounds
- Reverse osmosis to remove dissolved solids
- Ion exchange to remove the last traces of contaminants.

The treated effluent is stored in verification tanks, sampled and analyzed, and discharged to a state-approved land disposal site. Secondary aqueous waste generated from the ETF primary treatment train is concentrated to brine by evaporation, dried to a powder in a thin-film dryer, and packaged in 55-gallon drums. The drums are loaded out and transferred to lined burial trenches for disposal. The evaporator brine typically contains 25 to 45 wt% solids and is accumulated in two 5,000-gallon storage tanks while awaiting processing in the thin-film dryer. The ETF can generally accept low-level, *Resource Conservation and Recovery Act of 1976*-regulated, mixed low-level, and *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*-regulated liquid effluents, as well as industrial wastewater.
A transportation unloading facility allows liquid effluents to be received from other projects.

The design capacity of the ETF is 150 gal/min but varies with the composition of the effluents being treated. The nominal feed rate to the thin-film dryer is 0.6 gal/min. The ETF began operation in December 1995 and has a 30-year design life.

During the Cold War Era, the mission of the Hanford Site was to produce plutonium metal for the U.S. Department of Defense. The Hanford Site generated millions of gallons of high-level radioactive waste as a byproduct of plutonium production. The radioactive waste remains stored in underground tanks on the Hanford Site. The WTP is being constructed to vitrify those tank wastes and convert them to a stable form suitable for long-term disposal. Operation of the WTP is planned to start in 2010 and complete treating the tank waste in 2028. The WTP will generate a mixed low-level radioactive waste liquid effluent that will be transferred by pipeline to the ETF for treatment.

The projected flow rate and composition of WTP effluent will produce more evaporator brine than the ETF thin-film dryer is capable of processing. The nature of the solids is such that the resulting powder may require further treatment to stabilize mobile radionuclides prior to disposal.

Operation of the ETF thin-film dryer has also been problematic in the past. Groundwater and other feed streams that differ significantly in composition from that identified in the dryer design specification have been problematic. Feed streams outside the design specification coupled with a fluctuating feed density, caused by a control failure on the evaporator, resulted in hard material buildup on the internals of the dryer. The material buildup eventually caused failure of the rotor blades, and frequent maintenance has been required. For these reasons, an alternative technology is needed to process the evaporator brine to a waste form suitable for disposal.

Treating WTP liquid effluents in the ETF will generate an average of 8,700 L/day (2,300 gal/day) of evaporator brine containing 25 to 40 wt% solids, which is 3 times the current capacity of the existing dryer. The primary constituents of the brine will be sodium, ammonium, sulfate, nitrate, and bicarbonate. The majority of the bicarbonate will be converted to dissolved carbon dioxide by the addition of sulfuric acid. The carbon dioxide will subsequently be degassed. The brine will also contain small amounts of radioactive constituents. Composition of the brine will vary depending on tank waste feed to the WTP. The range of expected concentrations in the evaporator brine during the years that the WTP effluent will be received (2010-2028) is shown in Table A.1 of Appendix A.

4.0 SYSTEM REQUIREMENTS

The final disposal facility waste acceptance criteria have not been defined. The preferred alternative would generate a stabilized waste that would meet more rigid disposal criteria for land-disposal restricted waste, Category 3 waste, and wastes containing mobile radionuclides. The following sections further define the assumptions for disposal, process, and operational/maintenance requirements used to perform this study.

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4.1   DISPOSAL REQUIREMENTS

The ETF solid waste disposal site is assumed to be the Hanford Site mixed low-level burial grounds. The waste must meet requirements for the lined portion of the low-level burial grounds as described in *Hanford Site Solid Waste Acceptance Criteria* (HNF-EP-0063). Transportation and packaging of radioactive solid waste on the Hanford Site is performed in accordance with *Hanford Sitewide Transportation Safety Document (TSD)* (DOE/RL-2001-36).

Based on the projected ETF influent bounding case, the concentration of some of the heavy metals in the generated solid waste are approaching land disposal restriction limits, and would require stabilization prior to final disposal. This generated solid waste is also approaching the Category 3 limits and contains several mobile radionuclides.

As the Hanford Site cleanup mission progresses, higher-than-anticipated quantities of technetium-99 and iodine-129 are being disposed as radioactive solid waste. In response to this situation, much of the radioactive solid waste containing technetium-99 and iodine-129 is being stabilized before land disposal. As a solid waste generator, the ETF is evaluating new technologies to remove technetium-99 and iodine-129 before the drying process. By removing these radionuclides before the drying process, the amount of solid waste requiring stabilization will be minimized. Because of other studies being performed and final waste acceptance criteria is being developed in parallel, this study will not address the alternatives for stabilizing mobile radionuclides.

It was assumed during the selection of non-drying ETF STT treatment alternatives, that the ETF requirements are similar to the requirements applied to the low-activity waste during the Supplemental Treatment evaluations (Smets 2003). Therefore, conclusions from the Supplemental Treatment evaluation were carried forward into this evaluation and technologies such as resin encapsulation were eliminated because of their lack of proven longevity, susceptibility to radiolitic breakdown, or leaching characteristics and they were not reconsidered in this study. Of the remaining technologies, cast stone was the only one scaleable to ETF requirements.

4.2   PROCESS PARAMETERS AND REQUIREMENTS

The current forced convection evaporator typically removes 90 to 93% of the water resulting in a concentrated brine of between 25 to 40 wt% solids. Equipment rough-sizing estimations are based on 30 wt% solids, with a specific gravity of 1.5 (specific gravity estimate based on solids in 43 wt% solids feed, with specific gravity of 1.21 [ETF 2003]).

Particle size is an important component to dryer selection. Brine crystal particle sizes are assumed to be between 60 to 200 mesh. The composition is primarily sodium sulfate, and 99 wt% of sodium sulfate crystals are within that range.

Assuming the upstream processing remains unchanged, the flow rate of the projected feed stream is 6.8 L/min (1.8 gal/min) into the dryer. Any additional water that can be removed upstream will reduce this projected feed rate and corresponding duty on the dryer.

At a minimum, ETF STT modifications must meet the ETF secondary waste treatment requirements of the projected WTP feed stream and still allow the process to be configured to treat existing ETF feed streams. The solidified waste produced at ETF must be in a form that meets the waste disposal acceptance criteria and requires no additional processing before disposal at the Hanford Site. The projected feed rate and ionic concentrations for the influent from WTP and associated ETF evaporator brine, are provided in Appendix A. The projected ETF brine maximum yearly average concentrations are shown in Table 1 for the different stages of the STT.

The primary dissolved solids in the ETF brine feed stream are sodium sulfate and ammonium sulfate. However, the ETF STT treatment alternative is required to accept a flexible brine feed stream containing up to 3% carbonate and 1% nitrate salts as a percentage of the dissolved solids (based on the estimated percentages from Table 2).

4.3   OPERATIONAL AND MAINTENANCE REQUIREMENTS

The original design parameters of the ETF thin-film dryer were for a feed stream consisting of 36 wt% ammonium sulfate and 2 wt% sodium sulfate. Since startup of the ETF, the mission has grown to include other feed streams with a variety of constituents that have complicated the operation of the facility and resulted in maintenance challenges.

The multiple feed streams ETF accepts have different processing requirements and may have different waste disposal acceptance criteria. This study assumes different ETF feed stream requirements may be met by different configurations or selections of equipment within the facility. Therefore, multiple ETF STT treatment processes tailored to specific feed streams may be preferable to a single robust process.

This study also assumes that the current thin-film dryer is capable of handling the current ETF feed streams but is strained by certain streams and fluctuation in the feed density from the evaporator.

5.0   SELECTION OF ALTERNATIVES TO BE EVALUATED

There are numerous available treatment alternatives that could be made to the ETF STT to meet requirements defined in Section 4.0. The three different categories of treatment alternatives available are as follows:

- Optimization of the existing process without adding new equipment
- Addition of new drying equipment
- Addition of new cement-based stabilization equipment.

Figure 1 shows the list of treatment alternatives selected for evaluation in this study. The following sections discuss available alternatives for each of the three categories of treatment alternatives. The sections also include alternatives that were screened and determined to be inappropriate for this application, and were therefore eliminated from further consideration. Justifications are provided for alternatives that have been eliminated from further consideration.

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Figure 1. Secondary Treatment Train Treatment Alternatives

ETF = Effluent Treatment Facility.
STT = secondary treatment train.
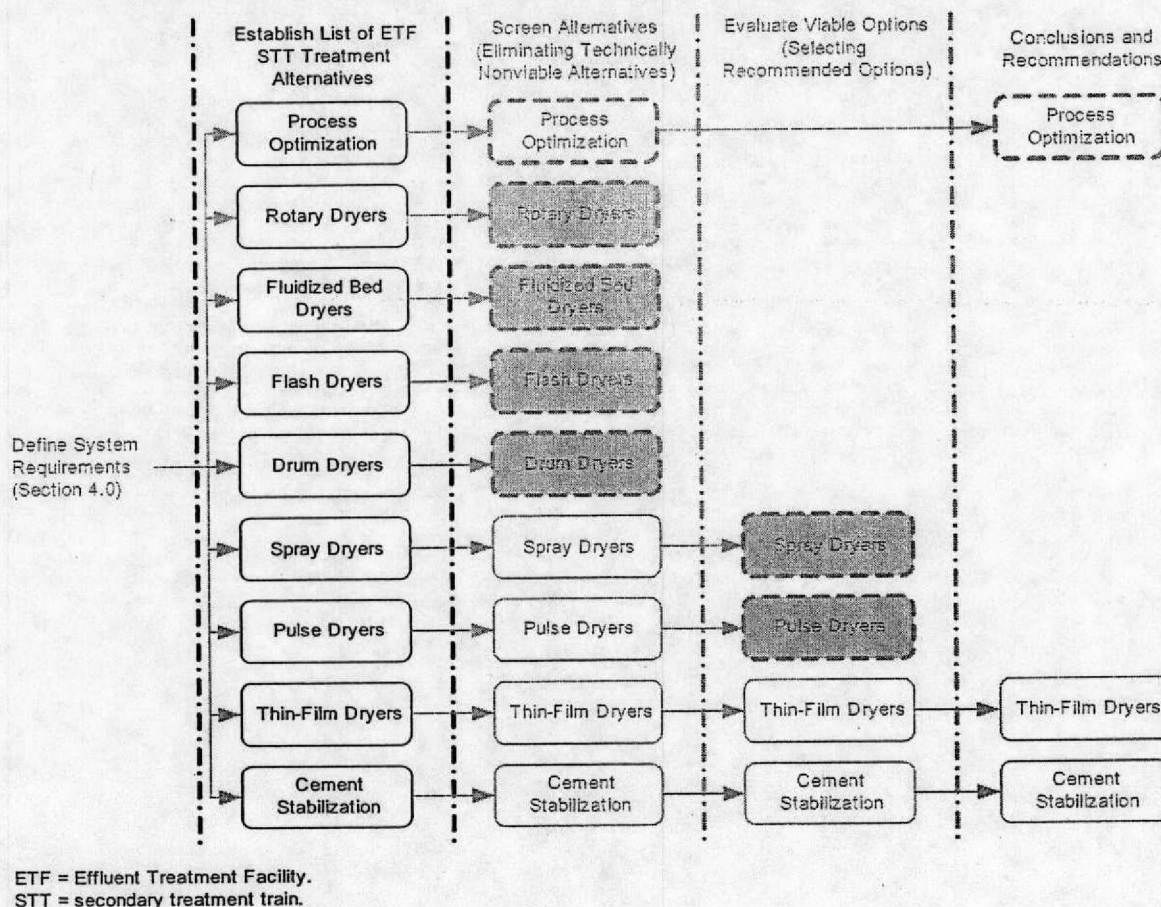
5.1 PROCESS OPTIMIZATION

Modifications can be made to the current STT process to optimize the process for changing feeds, without significant additional equipment. Modification to the amount of liquid removed at the evaporator, and chemical additions to enhance crystallization and precipitation, were evaluated as means of compensating and optimizing for changing feed compositions.

The current forced-convection evaporator typically removes 90 to 93% of water, resulting in a concentrated brine of between 25 to 40 wt% solids. The evaporator bottoms output is controlled by density and the inlet is controlled by volume. When the evaporator bottoms reach the set density, a valve automatically opens and the volume in the evaporator lowers. Another controller opens the evaporator feed inlet to maintain optimum volume in the evaporator body.

The evaporator bottoms density-based control system is vital to the operation of the drying system because it ensures a constant weight percent solids in the feed to the dryer. Fluctuations in the weight percent solids fed to the dryer shift the drying regions in the dryer and cause material buildups and agglomerations as well as drying inefficiency.

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The ability to easily alter the concentration of evaporator output by changing the density setting for discharge allows the system to be modified for changing feed streams without modifying other operating parameters. The system inherently modifies the required residence time by waiting until the density has reached the new setpoint.

The main problem with removing more water at the evaporator is that the precipitation of solids upstream of the dryer causes solids buildup in the system. The system was originally designed for transport of liquids without significant suspended solids. The concentrated brine storage tanks and other portions of the STT were not designed to accommodate solids in the process stream. However, the ETF groundwater feed currently generates solid gypsum in the evaporator. The evaporator is designed to tolerate solids production, but additional off-axis mixers had to be added to the concentrated brine storage tanks to keep the solids suspended (Scully 2004).

The composition of the projected evaporator bottoms indicates that concentration could be increased without significant solids production as long as the temperature does not drop significantly from its evaporator exit temperature of 100 to 104 °C (212 to 220 °F). Minor solids production, similar to gypsum solids currently processed, could be accommodated by the system.

Precipitation induced by the introduction of additional material is commonly used to remove dissolved solids from solution. An additional ion can be introduced to form a compound with the target ion. The resulting compound is less soluble and precipitates. Using a precipitation process for waste applications creates more waste material, and is therefore only recommended for removing ions that are problematic during drying.

Drying sodium nitrate is problematic because it has a high solubility at dryer temperatures and forms a sticky paste before it crystallizes. Carbonates are also problematic because they are scalers, however, with the addition of sulfuric acid, the majority of carbonate will be removed by conversion to gaseous carbon dioxide which in turn is removed by degasification before evaporation. The projected concentrations of the problematic constituents are anticipated to be overwhelmed by high concentrations of ammonium sulfate and sodium sulfate. Sulfate salts form large, fluffy crystals that readily fall out of solution and aid in drying of problematic constituents. This complimentary drying effect is known as bulking and is anticipated to eliminate drying problems associated with sodium nitrate and calcium. It is not considered necessary to use precipitation for the projected waste feed because ions targeted by a precipitation step will precipitate in the dryer, aided by the bulking effect of high concentrations of ammonium sulfate and sodium sulfate.

Given the possibility of a variation from the projected ETF influent bounding case, it is unadvisable to reduce the capacity of the dryer by assuming the evaporator can eliminate more water. The possibility that a problematic constituent may be solidified before the drying phase and cause a process problem is too great to warrant using an increased weight percent solid as a design parameter. Therefore, an evaporation process optimization should not be considered for use in a combined system to reduce the duty on a dryer. The reduction in duty is currently not a reliable assumption given the uncertainty of the future brine composition.

Process optimization should be considered to mitigate variations in the feed stream and prevent buildup in dryer systems during excursions from the expected feed composition. Process

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optimization (e.g., varying the density of the evaporator bottoms and refining the control of the density) can decrease the wear on thin-film dryers and reduce maintenance.

5.2 DRYING ALTERNATIVES

Seven drying alternatives that are capable of solidifying the projected ETF influent bounding case were evaluated. A description of these seven drying alternatives is provided in Appendix B. A down-select of the seven drying alternatives was performed by evaluating each against established screening criteria.

The screening criteria were selected to determine the dryer processes' suitability for ETF brine drying. Some key process criteria (e.g., thermal breakdown) are not included in this evaluation because they did not eliminate any processes or significantly differentiate between them. The screening criteria are as follows:

- Ability to accept liquid feeds
- Ability to accept slurry feeds
- Thermal efficiency
- Loss of solids (dusting/air entrainment)
- Air exhaust rate
- Free flowing product
- Ease in maintenance
- Ease in operations.

All evaluated drying technologies incorporate the existing thin-film dryer in parallel with the new system as depicted in Figure 2. The added capacity and operational flexibility of two parallel drying systems was determined to be a benefit to the facility, regardless of which drying technology is selected.

Figure 2. Process Flow of the Current System and Supplemental Dryer Alternative
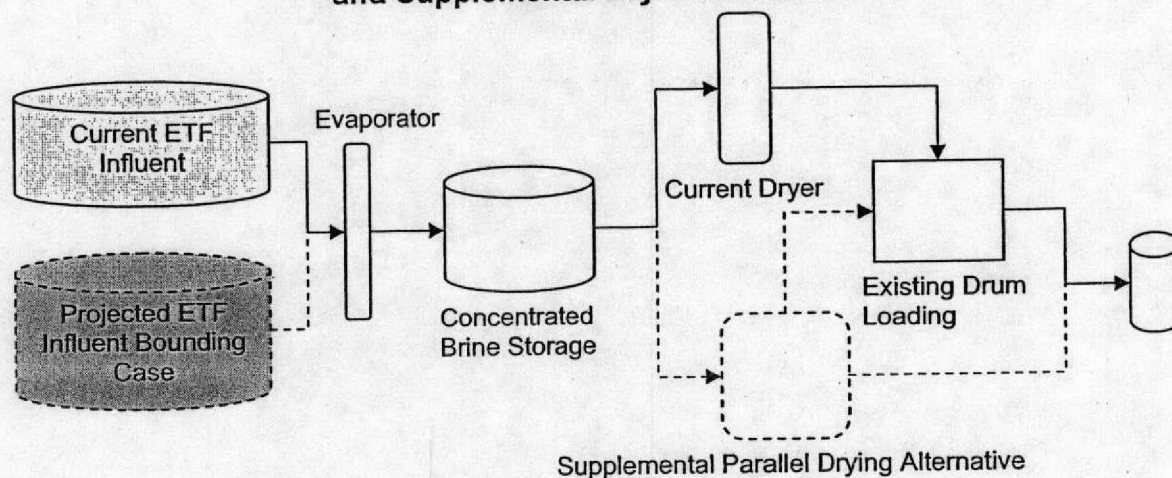
Note: Figure shows the current process flow with the supplemental parallel process flow in dashed lines. The existing drum loading system may be used by the supplemental process.

ETF = Effluent Treatment Facility.

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The drying technologies were given scores of 1 through 5 for the screening criteria, with a score of 1 meaning the technology failed to meet the criteria and a score of 5 meaning the technology completely met the criteria. Table 3 provides a summary of the evaluation of the dryer alternatives against the screening criteria. Appendix C provides justifications and details to support this evaluation.

Table 3. Summary of Drying Alternatives

Screening Criteria	Drying Alternatives						
	Rotary Dryer	Fluidized-Bed Dryer	Flash Dryer	Pulse Dryer	Spay Dryer	Drum Dryer	Thin-film Dryer
Accept liquid/solution feeds	1	1	1	5	5	3	5
Accept slurry feeds	1	2	1	4	4	2	5
Thermal efficiency	3	3	4	5	3	4	4
Loss of solids (dusting/ air entrainment)	4	1	1	3	2	4	5
Air exhaust rate	5	1	3	2	2	5	5
Free flowing product	2	5	2	5	5	2	4
Ease in maintenance	1	1	4	4	4	1	3
Ease in operation	1	1	2	3	2	2	4
Overall suitability	2.25	1.88	2.25	3.88	3.38	2.88	4.38

Based on the failure of rotary drying, fluidized bed drying, flash drying, and drum drying to meet the suitability criteria without significant modifications to the process, it is recommended that those technologies be eliminated from further consideration.

Spray drying, pulse drying, and thin-film drying were determined to be viable technologies for meeting the ETF secondary waste treatment requirements and were evaluated as alternatives along with the cement-based stabilization alternative.

5.3   STABILIZATION ALTERNATIVE

The field of alternative stabilization processes was narrowed to a single alternative, as described in Section 4.0, which is scalable to the ETF mission. The cement-based stabilization alternative was selected because of its proven history with similar waste streams and its safety, economy, and scalability. Stabilization through the addition of cementatous materials is traditionally employed when a robust physical waste form or shielding is required, or to reduce leachability of waste constituents.

Various formulations have been tested and used successfully in the nuclear waste industry. The dry material selection and formulation determines the characteristic of the final waste form, including its pre-setup flow properties and final waste form characteristics.

All waste cementation formulations include Portland cement in some concentration. One primary distinction of the formulations is the use of clays as a primary dry material, or the use of blast furnace slag and fly ash. Some formulations include all three materials.

The addition of clay yields a more fluid and workable cementation waste. This waste takes longer to set up and is suited for an application where the waste needs to be pumped or transferred considerable distances. The addition of blast furnace slag and fly ash yields a quick-setting, hard, non-porous waste form that is suited to operations where the waste is unloaded directly from the mixer into its final container.

Blast furnace slag and fly ash compositions react chemically with the waste form, converting waste constituents into their most insoluble forms. Clays are used primarily to bind and absorb waste constituents.

The cast stone stabilization process chemically converts the hazardous and radioactive constituents of the waste into their least soluble, mobile, or toxic forms. The curing process chemically incorporates the stabilized constituents into a monolithic solid of high structural integrity known as cast stone.

Cast stone was selected as an example of cement-based stabilization because it uses the formulation designed and tested for a waste that most closely resembles the projected ETF brine. Cast stone is a Portland cement, fly ash, and blast furnace slag mixture that contains small amounts of other dry materials to stabilize specific waste components in a less soluble form.

The cast stone process is ideally suited for high pH feed streams (pH 10-13) because they produce a cast stone mixture with a pH of approximately 12, which is ideal for converting mobile waste constituent into their most stable and insoluble forms. However, the cast stone process can accept feed streams with pH levels below the ideal range. Low pH feeds may require reduced waste loading to achieve optimum stabilization. The feed acceptance criteria for the cast stone process will allow most WTP waste to be fed directly to the Evaporator for concentration and then into the ribbon blender (mixer) for stabilization without any preprocessing.

Dry reagents are fed by screw conveyors to the mixer in precise quantities providing strength to the final product and inhibiting migration of soluble ions and radionuclides. A secondary dry reagent, ferrous sulfate monohydrate, is added to reduce hexavalent chromium and technetium to less soluble forms in order to meet leachability limits. Provisions are made for the addition of a plasticizer to either the evaporator or mixer using a metering pump to improve flow properties of the final product mix. The plasticizer increases flowability and allows for complete filling of the product container and decreased porosity of the cast stone product.

The cast stone formulation and equipment were designed to meet a rigorous set of requirements that are presented in detail in Appendix E. These requirements address leachability, compressive strength, and degradation. These requirements are more stringent than those anticipated for final disposal of the projected ETF secondary waste.

The cast stone mixing system utilizes ribbon-type mixers sized for 10 m^3 (353 ft^3) cast stone batches. The mixer receives batches of concentrated low-activity waste from the concentrated

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saltcake feed tanks and dry reagents from the dry reagent receipt, storage, and metering system. For the target 19 wt% waste loading, 5,000 L (1,320 gal) of concentrated brine is added to the mixer per 10 m³ (353 ft³) batch of immobilized brine cast stone. The corresponding quantities of dry reagents to be added per batch of immobilized brine are as follows:

- Portland cement – 1,072 kg (2,363 lb)
- Fly ash – 5,871 kg (12,943 lb)
- Blast furnace slag – 6,132 kg (13,519 lb)
- Ferrous sulfate monohydrate – 84 kg (185 lb).

Dry reagents are gravity fed to the mixer from their respective weigh bins during cast stone mixing. Mixing requires approximately 15 minutes per batch, after which the mixer gravity-drains the stabilized waste into an empty waste container staged in place by the immobilized brine containerization process.

The mixer operates continuously during the shift, including between batches. At the end of the shift, the mixer is rinsed using approximately 10 to 100 L (2.6 to 26 gal) of flush water. The resulting rinse is emptied into a dedicated container for subsequent disposal, or recycled back to the process.

Mixer overhead filters are prefilters that collect dust generated during dry reagent addition to minimize particulate load on the vessel vent system. The exhaust is then routed to the plant high-efficiency particulate air filtration system before discharge into the atmosphere.

The concentrated brine solution and the various reagents are thoroughly mixed in the batch ribbon mixer to provide a homogenous consistency and chemical stabilization. After mixing is completed, the final cast stone product is gravity-fed into a container on a batch basis. Both the mixer and container are sized for the same batch volume to mitigate overfilling of containers.

After the cast stone product has been emptied from the mixer into a container, the container is closed by applying a lid over the opening, radiologically surveyed, decontaminated if necessary, and transferred by material handling equipment to a staging area where curing and evaluation occurs. Figure 3 provides the process flow for the stabilization alternative.

Figure 3. Process Flow for Stabilization Alternative
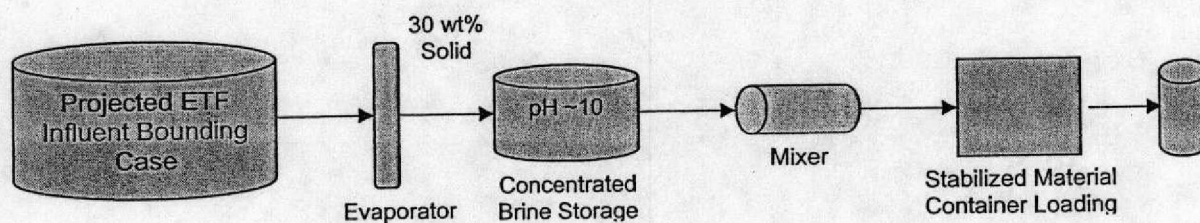
ETF = Effluent Treatment Facility.

6.0 EVALUATION CRITERIA

Three down-selected drying alternatives and the stabilization alternative were assessed using a set of evaluation criteria to determine the optimal alternative for achieving the goals of the ETF as depicted in Figure 4. The evaluation criteria encompass the full spectrum of technical, economic, environmental and safety considerations. The evaluation criteria are as follows:

- Principle of operation
- Equipment used
- Solids handling, packaging, and characteristics
- Operations and controls
- Utilities and support services
- Facility/building requirements
- Compatibility and integration with existing systems
- Capacity and flexibility to accommodate changes in feed volume and composition
- Changes required to implement the alternative
- Installed cost
- Cost of operation
- Reliability, availability, and maintainability
- Hazards and safety considerations
- Compliance with applicable requirements.

The detailed descriptions of the evaluation criteria and the scoring of each alternative are provided in Appendix D. The following sections provide a description of the evaluation criteria and the basis for the evaluation score.

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Figure 4. Road Map – Selection of Recommended Secondary Treatment Train Treatment Alternatives
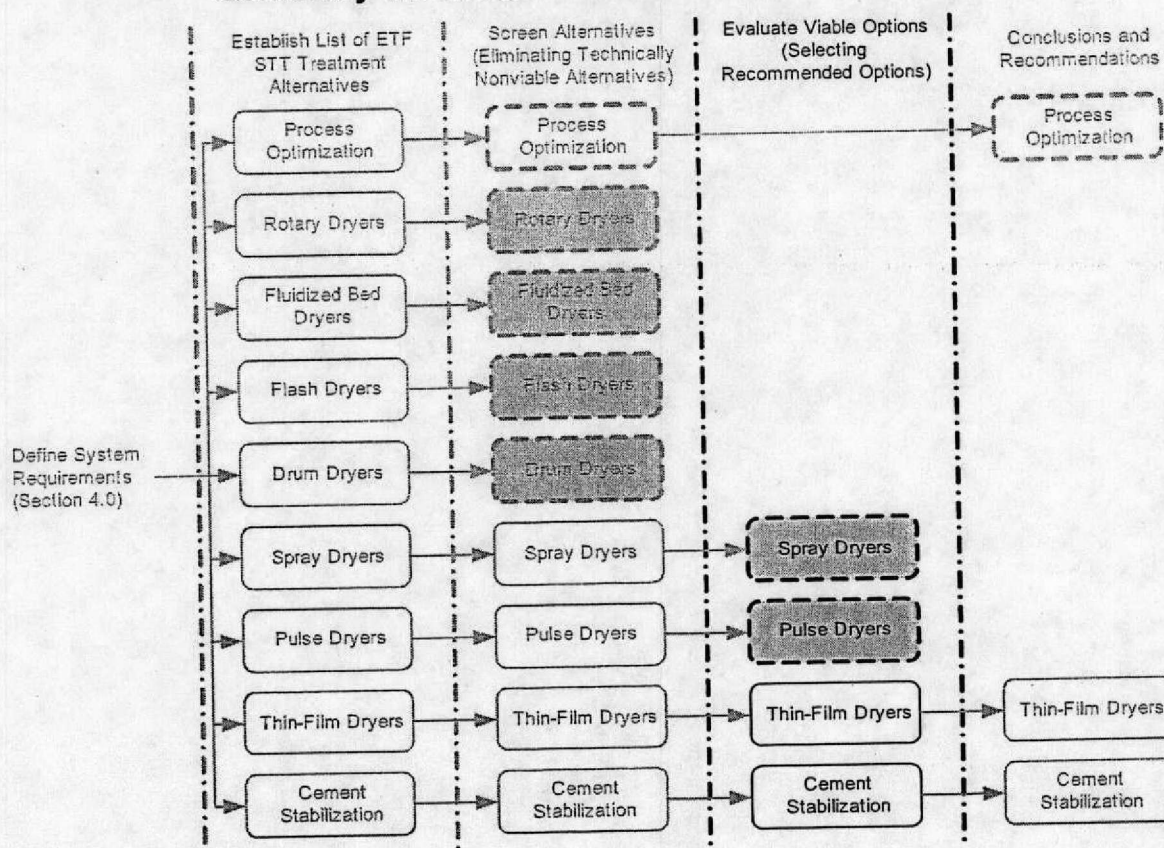
ETF = Effluent Treatment Facility.
SST = secondary treatment train.

6.1 PRINCIPLE OF OPERATION

The principle of operation evaluation includes a technical description of each alternative, including a process description and key elements that may be modified or added to the existing ETF process. The suitability of the principle of operation to meet the ETF requirements, including advantages and disadvantages, is included in the evaluation. The score for this evaluation is based on the suitability of the principle of operation to meet the ETF requirements.

6.2 EQUIPMENT USED

The equipment used evaluation includes a technical description of the types of equipment required in each alternative to modify or augment the existing ETF. The score for this evaluation is based on equipment availability and previous industrial experience in similar applications.

6.3 SOLIDS, HANDLING, PACKAGING, AND CHARACTERISTICS

The solids handling, packaging, and characteristics evaluation includes a technical description of the alternatives for solids handling and packaging operations, and the resulting characteristics of

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the solids produced. The score for this evaluation is based on the alternatives history of use in similar waste applications, projected ability to meet the disposal facility waste acceptance criteria, and the degree to which previously used systems would differ from the system required for this application.

6.4   OPERATIONAL CONTROLS

The operational controls evaluation includes a technical description of the operational control inherent to each alternative. The score for this evaluation is based on the ease of control, tolerance for disruption, and whether the control requirements match the control scheme of the ETF.

6.5   UTILITIES AND SUPPORT SERVICES

The utilities and support services evaluation includes a technical description of the utility and support service requirements for each alternative. The score for this evaluation is based on how onerous the requirements are, and on availability of utilities and services at the ETF.

6.6   FACILITY/BUILDING REQUIREMENTS

The facility/building requirements evaluation includes a description of characteristics of alternatives that will require changes to the existing facility/building. A description of any additional new structures or buildings required to accommodate each alternative is included. The score for this evaluation is based on how onerous the requirements and modifications are to the ETF.

6.7   COMPATIBILITY AND INTEGRATION WITH EXISTING SYSTEMS

The compatibility and integration with existing systems evaluation includes a description of compatibility and integration issues outside the scope of utilities, services, control systems, facility/building modifications, and the process changes. These may include requirements for additional ventilation, offgas, shielding for radiation, high temperatures, noise, and training. The score for this evaluation is based on how onerous the requirements are to the ETF.

6.8   CAPACITY AND FLEXIBILITY TO ACCOMMODATE CHANGES IN FEED VOLUME AND COMPOSITION

The capacity and flexibility to accommodate changes in feed volume and composition evaluation includes a technical description of each alternative's flexibility and any specific limitations that have been proven problematic to alternatives. The score for this evaluation is based on the alternatives ability to accommodate 6.8 L/min (1.8 gal/min) at the full range of anticipated concentrations as shown in Table 1.

6.9   CHANGES REQUIRED TO IMPLEMENT THE ALTERNATIVE

The changes required to implement the alternative evaluation includes a technical description of major modifications necessary to facilitate each alternative. Other changes and implementation

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requirements, including administrative controls and operational consideration, are described for the various alternatives.

6.10 INSTALLED COST

The installed cost evaluation includes a list of required equipment and primary interfaces required for installation. The score for this evaluation is based on how expensive installation will be compared to the other alternatives.

6.11 COST OF OPERATION

The cost of operation evaluation includes relative utility requirements for operation, and the cost of any feed material required for operation. The score for this evaluation is based on how expensive operation is compared to other alternatives.

6.12 RELIABILITY, AVAILABILITY, AND MAINTAINABILITY

The reliability, availability, and maintainability evaluation includes each alternative's operational history on similar process missions and predicted relative performance. Issues considered likely to impact alternative performances are also included in this evaluation.

6.13 HAZARDS AND SAFETY CONSIDERATIONS

The hazards and safety considerations evaluation details distinctions between alternatives with respect to hazards and safety. Inherent differences that make an alternative more or less safe will be described. The score for this evaluation is a comparative ranking of the degree of safety inherent to each alternative.

6.14 COMPLIANCE WITH APPLICABLE REQUIREMENTS

The compliance with applicable requirements evaluation details any foreseen difficulty with compliance. This section also includes information about any similar application on the technologies and performance information reflecting upon the suitability of each alternative to meet the requirements, or indicate that similar applications could not be identified.

7.0 EVALUATION OF SELECTED ALTERNATIVES

The evaluation criteria were weighted to give more weight (10%) to criteria that affect the feasibility of successfully utilizing the alternatives, and give less weight (5%) to criteria that primarily affect the difficulty of successfully utilizing the alternative (e.g., an alternative that has a principle of operation unsuited for the task affects its feasibility, where are an alternative that has a operations and control unsuited for the task affects its difficulty). Successful utilization of an alternative was defined as safe operation and maintenance by the ETF staff in accordance with current facility and site administrative procedures that will not require excessive maintenance or modifications to the technology.

The alternatives were given scores of 1 through 5 for the evaluation criteria, with a score of 1 meaning the technology failed to meet the criteria and a score of 5 meaning the technology completely met the criteria. Table 4 provides a summary of the ratings of the alternative against the evaluation criteria, and the resulting weighted scores. Appendix D provides justifications and details to support this evaluation.

Table 4. Summary of Secondary Treatment Train Treatment Alternatives

Evaluation Criteria	Alternative 1 Spay Dryer		Alternative 2 Pulse Dryer		Alternative 3 Thin-Film Dryer		Alternative 4 Cement Stabilization	
	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted
Principle of operation	2	0.2	3	0.3	5	0.5	5	0.5
Equipment used	2	0.2	2	0.2	5	0.5	5	0.5
Solids handling, packaging, and characteristics	2	0.2	3	0.3	3	0.3	5	0.5
Operations and controls	2	0.1	2	0.1	4	0.2	4	0.2
Utilities and support services	2	0.1	3	0.15	4	0.2	2	0.1
Facility/building requirements	2	0.1	3	0.15	5	0.25	3	0.15
Compatibility and integration with existing systems	2	0.1	3	0.15	5	0.25	4	0.2
Capacity and flexibility to accommodate changes in feed volume and composition	1	0.1	4	0.4	4	0.4	5	0.5
Changes required to implement the alternative	2	0.1	3	0.15	4	0.2	3	0.15
Installed cost	3	0.15	3	0.15	3	0.15	4	0.2
Cost of operation	2	0.1	4	0.2	4	0.2	4	0.2
Reliability, availability, and maintainability	2	0.2	4	0.4	4	0.4	4	0.4
Hazards and safety considerations	4	0.2	3	0.15	5	0.25	4	0.2
Compliance with applicable requirements	4	0.4	4	0.4	5	0.5	5	0.5
Total		2.25		3.2		4.4		4.3

8.0   CONCLUSIONS AND RECOMMENDATIONS

Nine alternatives were considered for management of the ETF secondary waste. Alternatives included process optimization, seven drying alternatives, and a stabilization alternative. A down-select of the seven drying alternatives was performed by evaluating each against the screening criteria. Three down-select drying alternatives and the stabilization alternative were then evaluated against 14 weighted evaluation criteria to define a preferred alternative.

A drying alternative using a larger thin-film dryer that operates parallel to the existing dryer is recommended as the preferred drying alternative. Drying the ETF secondary waste is optimal for waste reduction. However, because there may be issues with performance of the powder waste form at final disposal, the stabilization alternative has been maintained.

Thin-film drying is the most robust and reliable method for solidifying the projected ETF feed stream, and the recommended technology to meet the evaluation criteria, as detailed in the evaluation in Appendix D.

The addition of a supplemental parallel thin-film dryer, approximately twice the size and capacity of the current ETF dryer, is the recommend method for solidifying the projected WTP brine stream to meet no-free-water waste disposal acceptance criteria. If more stringent waste disposal acceptance criteria (e.g., stabilization or shielding) are establish for the ETF solid waste from WTP brine, then cement stabilization is the recommend method for solidifying the projected WTP brine stream.

Skid-based thin film dryer units similar to the existing ETF dryer are estimated to cost $1.5 million by the vendor. These dryer units are capable of solidifying 6.8 L/min (1.8 gal/min) of the ETF boundary case influent. Further equipment details are provided in Appendix C, Section 7.

The choice of a supplemental thin-film dryer over other drying technologies has other advantages that were not directly taken into account during the evaluation including proven operational history with Hanford Site brine streams at ETF. The ETF operational and maintenance experience with thin-film dryers and an understanding of thin-film dryer system dynamics and controls. The existing administrative controls, including procedures and other documents and existing training, favor the use of a second thin-film dryer.

However, because there may be issues with performance of the powder waste form at final disposal, the stabilization alternative is the preferred alternative. Because the current forecast is preliminary and there is concern that treatment of the influent from the WTP and Supplemental Treatment Facilities may generate a waste that is not Land Disposal Restrictions compliant, is above radiological Category 3, and/or contains mobile radionuclides, stabilization provides the flexibility to meet final disposal requirements.

The stabilization alternative is a cement-based stabilization, similar to cast stone. A stabilization system provides the additional flexibility of using different cement-based stabilization formulas

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to meet the final disposal waste acceptance criteria. Once the final disposal facility waste acceptance criteria have been defined, a tailored formulation can be selected if necessary.

Cement stabilization is a technology based on lifetimes of research; however, the community of stabilization experts is relatively small. There are a few world-recognized experts in cement stabilization whose work is the cornerstone for the entire technology. Any cement stabilization method research upon which significant decisions are based on should be evaluated and concurred with by at least one of the experts in the field. Any search for the closest analog for ETF influent bounding case for stabilization in the waste cement stabilization industry should consider the full range of concentration produceable by evaporation and the full range of constituent produceable by pH adjustment. It is likely that a very close analog can be found with the possible range of concentration and constituent produceable at ETF.

9.0   REFERENCES

Comprehensive Environmental Response, Compensation, and Liability Act of 1980,
      Public Law 96-150, 94 Stat. 2767, Title 26, 42 USC 9601 et seq.

DOE/RL-2001-36, 2001, *Hanford Sitewide Transportation Safety Document (TSD),*
      U.S. Department of Energy, Richland Operations Office, Richland, Washington.

ETF, 2003, Client-Supplied Information in SOW, referred to as "Evaporator Operation,"
      Fluor Hanford, Inc., Richland, Washington.

HNF-EP-0063, 1998, *Hanford Site Solid Waste Acceptance Criteria,* Rev. 0, CH2M HILL
      Hanford Group, Inc., Richland, Washington.

Resource Conservation and Recovery Act of 1976, Public Law 94-580, 90 Stat. 2795,
      42 USC 901 et seq.

Scully, D., 2004, "Notes from phone consultation with Donald Scully," Cognizant Engineer
      SWS system, during ground-water modifications).

Smets, J., 2003, "Contract Number 18548 Transmittal of Deliverables – Task 2 – Deliverable
      Number 3.2-5, Table 4-1 – 100% Preconceptual Design Report" (Letter FL-2003-
      65300971-006 to R. W. Powell, CH2M HILL, August 20), Fluor Federal Services,
      Richland, Washington.

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APPENDIX A
BOUNDING CASE 200 AREA EFFLUENT TREATMENT FACILITY FEED COMPOSITION

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Table A.1. Projected ETF Influents for 2010 through 2029

	Units	Molecular Weight	Ionic Charge	Evaporator Brine 2010	Evaporator Brine 2011	Evaporator Brine 2012	Evaporator Brine 2013	Evaporator Brine 2014	Evaporator Brine 2015	Evaporator Brine 2016	Evaporator Brine 2017	Evaporator Brine 2018	Evaporator Brine 2019	Evaporator Brine 2020	Evaporator Brine 2021	Evaporator Brine 2022	Evaporator Brine 2023	Evaporator Brine 2024	Evaporator Brine 2025	Evaporator Brine 2026	Evaporator Brine 2027	Evaporator Brine 2028
Year				2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Volume	gal/yr			7.5E+05	1.0E+06	7.8E+05	8.3E+05	8.2E+05	7.4E+05	8.1E+05	8.4E+05	8.5E+05	8.3E+05	8.3E+05	8.3E+05	8.3E+05	8.3E+05	8.3E+05	8.3E+05	8.3E+05	8.3E+05	8.3E+05
pH																						
Ca	mg/L	40.08	2	1.5E-01	7.3E-02	1.3E-01	9.9E-02	7.1E-02	1.6E-01	1.3E-01	3.1E-01	1.9E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01	1.5E-01
Fe	mg/L	55.847	3	3.8E-02	4.0E-02	1.2E-01	1.3E-01	3.3E-02	1.8E-01	6.1E-02	4.0E-02	7.7E-02	7.8E-02	7.8E-02	7.8E-02	7.8E-02	7.8E-02	7.8E-02	7.8E-02	7.8E-02	7.8E-02	7.8E-02
Na	mg/L	22.98977	1	6.7E-04	6.1E-04	6.4E-04	5.3E-04	6.2E-04	5.5E-04	5.3E-04	5.3E-04	5.1E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04
Cl	mg/L	35.453	-1	7.6E+00	1.7E-01	1.1E-01	1.8E-01	3.3E-01	2.8E-01	2.8E-01	1.0E-01	2.5E-01	1.9E-01	1.9E-01	1.9E-01	1.9E-01	1.9E-01	1.9E-01	1.9E-01	1.9E-01	1.9E-01	1.9E-01
CO3	mg/L	60.0092	-2	3.6E-03	3.2E+03	3.5E+03	3.4E+03	3.3E+03	3.5E+03	3.5E+03	3.5E+03	3.2E+03	3.4E+03	3.4E+03	3.4E+03	3.4E+03	3.4E+03	3.4E+03	3.4E+03	3.4E+03	3.4E+03	3.4E+03
F	mg/L	18.9984	-1	1.0E+00	1.1E+00	1.5E+00	2.1E+00	2.5E+00	4.0E-01	1.5E+00	1.5E+00	1.8E+00	1.3E+00	1.3E+00	1.3E+00	1.3E+00	1.3E+00	1.3E+00	1.3E+00	1.3E+00	1.3E+00	1.3E+00
NH3	mg/L	18.0383	1	2.1E-04	2.6E-04	2.3E-04	2.4E-04	2.6E-04	2.3E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04	2.4E-04
NO2	mg/L	46.0055	-1	5.0E-01	4.8E-02	6.8E-02	3.6E-01	3.5E-01	3.9E-01	3.2E-01	1.8E-01	3.0E-01	3.5E-01	3.5E-01	3.5E-01	3.5E-01	3.5E-01	3.5E-01	3.5E-01	3.5E-01	3.5E-01	3.5E-01
NO3	mg/L	62.0049	-1	8.3E-02	4.6E-02	6.8E-02	6.5E-02	6.1E-02	6.1E-02	6.5E-02	7.4E-02	3.0E-01	6.4E-02	6.4E-02	6.4E-02	6.4E-02	6.4E-02	6.4E-02	6.4E-02	6.4E-02	6.4E-02	6.4E-02
PO4	mg/L	103.0059	-3	5.5E+00	2.9E+00	4.3E+00	5.9E+00	1.5E-01	1.3E-01	1.1E-01	2.5E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01
SO4	mg/L	96.0576	-2	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05	1.7E-05
OH	mg/L	17.0073	-1	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05	2.5E+05
TDS	mg/L																					
TOC	mg/L																					

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Table A.2. Projected Bounding Case ETF Influents
Primary Salt Forming Ions (Contributing to >98% of TDS)

	Average Influent	pH Adjusted Influent	Evaporator Brine	Evaporator Brine		Molecular Weight	Moles/L
Ca- Min	8.68E-03	8.68E-03	7.08E-02	0.00%	of TDSs		
Ca- Max	4.73E-02	4.73E-02	1.62E-01	0.00%	of TDSs		
Fe- Min	3.79E-03	3.79E-03	3.76E-02	0.00%	of TDSs		
Fe- Max	1.62E-02	1.62E-02	1.48E-01	0.00%	of TDSs		
Na- Min	5.67E+03	5.67E+03	5.07E+04	20.30%	of TDSs	22.98977	2207.29
Na- Max	8.54E+03	8.54E+03	5.66E+04	22.63%	of TDSs	22.98977	2461.28
Cl- Min	6.98E-01	6.98E-01	6.97E+00	0.00%	of TDSs		
Cl- Max	4.00E+00	4.00E+00	3.26E+01	0.01%	of TDSs		
CO3- Min	7.16E+03	3.58E+02	3.22E+03	1.29%	of TDSs	60.0092	53.7313
CO3- Max	1.09E+04	5.43E+02	3.57E+03	1.43%	of TDSs	60.0092	59.5382
F- Min	5.30E-02	5.30E-02	4.84E-01	0.00%	of TDSs		
F- Max	3.09E-01	3.09E-01	2.52E+00	0.00%	of TDSs		
NH3- Min	2.11E+03	2.11E+03	2.10E+04	8.42%	of TDSs	18.0383	1166.59
NH3- Max	4.37E+03	4.37E+03	2.59E+04	10.38%	of TDSs	18.0383	1438.15
NO2- Min	2.28E+00	2.28E+00	2.70E+01	0.01%	of TDSs	46.0055	0.58622
NO2- Max	5.69E+00	5.69E+00	5.02E+01	0.02%	of TDSs	46.0055	1.09145
NO3- Min	6.72E+01	6.72E+01	4.79E+02	0.19%	of TDSs	62.0049	7.72804
NO3- Max	9.44E+01	9.44E+01	8.31E+02	0.33%	of TDSs	62.0049	13.3948
PO4- Min	4.89E-01	4.89E-01	2.91E+00	0.00%	of TDSs		
PO4- Max	3.17E+00	3.17E+00	1.47E+01	0.01%	of TDSs		
SO4- Min	1.30E+00	1.68E+04	1.68E+05	67.15%	of TDSs	96.0576	1747.76
SO4- Max	5.86E+00	2.85E+04	1.70E+05	67.82%	of TDSs	96.0576	1765.03
TDS- Min	1.52E+04	2.50E+04	2.50E+05	100.00%	of TDSs		
TDS- Max	2.41E+04	4.21E+04	2.50E+05	100.00%	of TDSs		

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APPENDIX B
DRYING ALTERNATIVES

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FIGURES

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B1.0 ROTARY DRYER

A rotary dryer consists of a revolving cylindrical shell horizontally or slightly inclined toward the outlet, as shown in Figure B.1. Wet feed enters one end of the cylinder and dry material discharges from the other end. As the shell rotates, internal flights lift the solids and cascade them down through the interior of the shell. Rotary dryers are heated by direct contact of gas with the solids, by hot gas passing through an external jacket, or by steam condensing in a set of longitudinal tubes mounted on the inner surface of the shell. Airflow may be parallel or counter-current. The agitation of feed material and the large area of feed material exposed to the air produces high drying rates and a uniformly dried product.

Figure B.1. Typical Rotating Dryer, Cutaway Showing Baffles and Picture
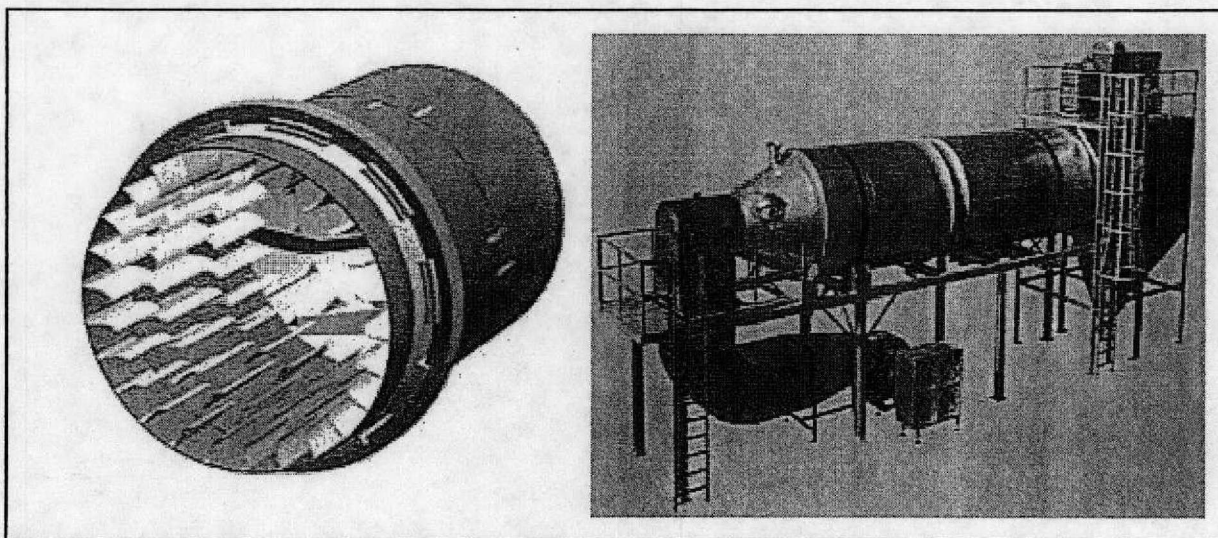
Rotary drying technology is almost exclusively used for solids and not for solutions or slurries. This method is especially suitable for materials that tend to mat or stick together in belt or tray dryers.

In general, the rotary steam tube dryer operates at a lower temperature than other types of dryers. It also rotates at a slower speed than other rotary dryers allowing material to tumble gently through the heating tubes (*Rotary Dry Information Web Page* [Simon 2004a]). Because the drying medium is steam within the tubes, as opposed to the hot gas flow required by other rotary dryers, a lower air velocity through the dryer is required. This reduces the amount of product carried through the dryer in the exhaust gas stream (Simon 2004a).

The counter-current air-heated rotary dryer is widely used for salt (NaCl), sugar, and granular and crystalline materials that must be kept clean and may not be directly exposed to hot flue gasses.

Rotary dryers have significant limitations. Wet and sticky products cause clogging of the inlet and transfer section of the dryer drum. Flights are often clogged, reducing their carrying capacity and the volume of the curtains. Chains and knockers can mitigate this somewhat, but

the industry spends far too much valuable processing time digging out blockages of built-up material ("A Review of Major Dryer Types, Rotary Dryers, Part 3" [Traub 2002]).

Processing large particles causes noise, and the impact of the particles from the fall may cause size reduction. Cascade dryers have difficulty providing accurate temperature control, particularly if there is variation in feed characteristics. This results in variations in dried product characteristics and, most commonly, in final moisture content. Direct cascade dryers are simple machines with aggressive material handling. This can result in significant wear and high maintenance costs. In addition, a large rotating mass (e.g., a drum) has numerous high-maintenance aspects and components. In a system that is well designed, engineered, and maintained, these maintenance issues are controlled. This, however, is more the exception than the rule, and quick-fix patches do nothing to improve the reputation of these systems (Traub 2002). Table B.1 summarizes key parameters of typical rotary dryer application.

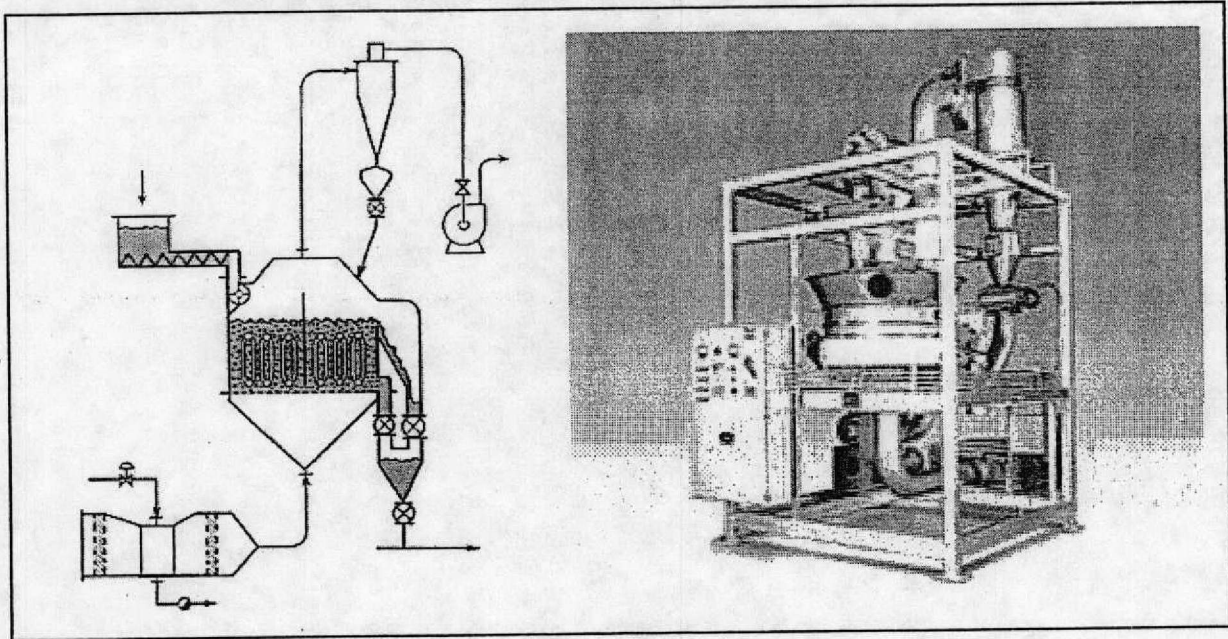### Table B.1. Typical Rotary Dryer Application

Application:	Drying solids
Waste Application:	No liquid drying applications
Application Similar to ETF Brine:	No liquid drying applications
Feed Material Weight % Solids:	85 to 99
Feed Rates:	>10 ft^3/min (2 m^3/min)
Dimensions:	3- to 10-ft- (1- to 3-m-) diameter*, 30 to 100 ft (10 to 30 m) long
Temperatures:	250 to 350 °F (120 to 175 °C) for steam-heated air

*Source: McCabe 1985.

B2.0 FLUIDIZED-BED DRYER

A fluidized-bed dryer suspends and excites solids in a stream of heated, drying gas. Fluidized-bed dryers have been applied to a wide variety of applications and have an accordingly wide variety of configurations, for both batch operation and continuous operation. Typically, particles are fluidized by hot air in a "boiling-bed" unit as shown in Figure B.2. Mixing and heat transfer are very rapid. Wet feed is admitted to the top of the bed, and dry product is taken out from the side, near the bottom.

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Figure B.2. Typical Flash Dryer Diagram and Picture

A fluidized-bed drying technology is almost exclusively used for solids and not for solutions or slurries. The feed may take the form of powders, granules, crystals, pre-forms, and non-friable agglomerates ("Fluid Bed Dryers" [Traub 2001b]).

The technology for processing liquids in a fluidized-bed system requires use of a host media (e.g., sand) that is constantly dried and re-wetted. If the host media is too robust, then it will abrade the chamber. If the host media is too fragile, then it will break down and require downstream removal from the air stream. The host media must be segregated from the dry material and reintroduced to combine with new feed material. The recycling and segregation of host material typically utilizes more equipment than the drying process. Therefore, the host media fluidized-bed dryer was not considered a viable option for this evaluation.

In the dryer shown in Figure B.2 there is a random distribution of residence time; the average time a particle stays in the dryer is typically 30 to 120 seconds when only surface liquid is vaporized, and 15 to 30 minutes if there is internal diffusion. Small particles are heated to the exit temperature of the fluidizing gas; consequently, thermally sensitive materials must be dried in a relatively cool suspending medium. Hot inlet gas mixes so rapidly that temperature throughout the bed is virtually uniform. If fine particles are present either from the feed or from particle breakage, then there may be considerable solids carried over with the exit gas and a dust collection system (e.g., a cyclone and baghouse, scrubber, or electrostatic precipitator [ESP]) must be utilized. Fluidized-bed systems require dust control because of the nature of the gas/product interaction.

Fluidized-bed dryers are commonly provided with both forced and induced draft fans. Static pressure required for fluidization can be high, requiring large motors on the fans (particularly forced draft or fluidizing fans), depending on the product bulk density. The systems are designed to provide zero or null pressure points in the expansion chamber above the bed.

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Fluidized-bed dryers are compact and have good control over drying conditions, relatively high thermal efficiencies, and high drying rates. The dryer has high rates of heat and mass transfer and, consequently, short drying times. Drying can take place with air temperatures below 212 °F (100 °C), or as high as 338 °F (170 °C) and higher depending on the product/process. Fluidized-bed drying is often applied as a last drying step after spray drying (CIAA 2002).

Fluidized-bed dryers are a gentle method of handling many products. They require relatively small real estate and are low maintenance because of few moving components in the system (Traub 2001b). Their principle limitations include the following (Traub 2001b):

- Inadequate bed formation because of poor fluidizing plate designs

- Relatively high operating costs associated with the power requirements for the fans

- Potential reduction of product size because of attrition and impact

- The possibility of product buildup in the wind box on loss of power

- Technology for processing of liquids in fluidized-bed systems requires the use of a host media.

Fluidized-bed dryers tend to agglomerate material, which may be an advantage or disadvantage, depending on product characteristics and operational requirements (Traub 2001b). Table B.2 summarizes key parameters of typical fluidized-bed dryer application.

Table B.2. Typical Fluidized-Bed Dryer Application

Application:	Drying solids
Waste Application:	No liquid drying applications
Application Similar to ETF Brine:	No liquid drying applications
Feed Material Weight Percent Solids:	70 to 90
Feed Rates:	1 to 100 gal/min (4 to 400 L/min)
Dimensions:	30 to 50 ft (10 to 20 m) tall, 5- to 10-ft- (1- to 3-m-) diameter
Temperatures:	212 to 340 °F (100 to 170 °C)*

*Source: CIAA 2002.

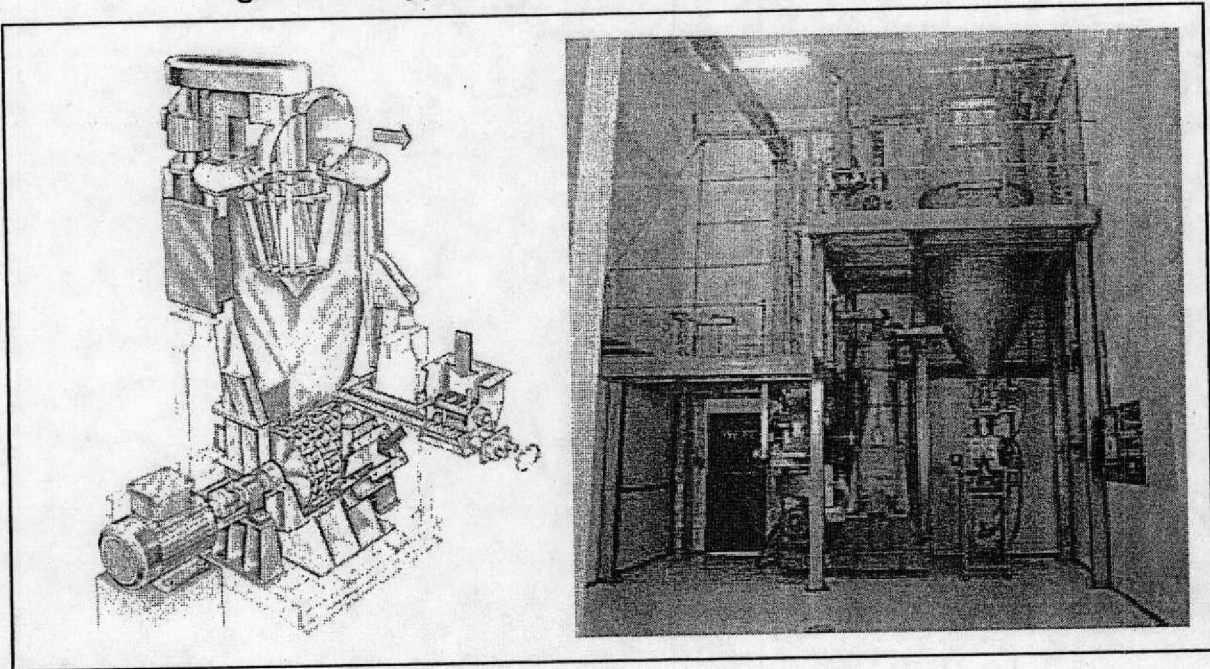## B3.0 FLASH DRYER

A flash dryer transports wet, pulverized solids in a hot gas stream for a few seconds. A typical flash dryer is shown in Figure B.3. Drying occurs during transportation when heat is rapidly transferred from the hot gas to the suspended solids. Typically less than three or four seconds is required to evaporate all of the available moisture from solid particulates. Gas temperature is

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typically 1200 °F (649 °C) at the inlet, but the residence time of the particles in the gas is so short that the temperature rarely exceeds 100 °F (38 °C) during drying. Therefore, flash drying may be applied to sensitive materials that in other dryers would have to be dried less efficiently over a longer period of time at lower temperatures.

Figure B.3. Typical Flash Dryer, Diagram and Picture

Flash drying technology is almost exclusively used for solids, and not for solutions. Flash dryers are an efficient method of drying products (e.g., slurries, pastes and sludge [most with back mixing], friable filter cakes, powders and granules). The feed must have a relatively consistent particle size to facilitate transfer without segregation and buildup. Flash dryers operate effectively on throughput rates varying from a few kilograms per hour up to several hundred tons per hour (based on the bulk density of the product). The resulting product may have residual moisture varying from 0 to 12% depending on operating parameters or the percentage of bound moisture contained in the feed.

Flash dryers require little real estate relative to throughput. The flash tube of the dryer is flexible and can be routed to suit facility constraints. Flash dryers can effectively dry products, elevate them, move them around a facility, or preheat them for successive processes. Flash dryers have few moving parts and can be designed to handle extremely abrasive products with replaceable wear components ("Flash Drying" [Traub 2001a]).

Flash drying is a continuous process with the dryer being directly or indirectly fired. Flash dryers are inherently co-current dryers with the hottest air contacting the wettest product. They operate at inlet temperatures varying from ambient dehumidified air for sensitive products, to more than 1100 °F (600 °C) for robust products. Because the system has relatively low residence time and moisture is flashed off, a significant amount of evaporative cooling takes place. This allows for the use of higher inlet temperatures than in many other dryers, without

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unduly heating the product. Higher inlet temperatures also increase the overall dryer efficiency (Traub 2001a).

Flash dryers have large amounts of entrained air and accordingly large exhaust systems. The exhaust systems are normally dedicated to a single dryer and not connected to facility filtration.

Loss of power to the dryer will cause product to fall out of suspension and build up in the dryer base and feed throat. If the product hardens under heat, this may cause a blockage requiring significant time to remove. Because of the relatively high velocities, particle size may be reduced due to attrition and impact. High velocities also may contribute to premature component wear if the system is not designed to inhibit it (Traub 2001a). Table B.3 summarizes key parameters of typical flash dryer application.

Table B.3. Typical Flash Dryer Application

Application:	Drying solids
Waste Application:	No liquid drying applications
Application Similar to ETF Brine:	No liquid drying applications
Feed Material Weight % Solids:	80 to 99
Feed Rates:	1 to 40 gal/min (4 to 200 L/min)
Dimensions:	15 to 30 ft (5 to 10 m) tall, 9- to 20-ft- (3- to 7-m-) diameter
Temperatures:	Ambient dehumidified air to >1100 °F (600 °C)

B4.0 DRUM DRYERS

A drum dryer consists of one or more heated metal rollers on the outside of which a thin layer of liquid is evaporated to dryness. Dried solid is scraped off the rollers as they slowly revolve. A typical drum dryer, a double-drum unit with center feed, is shown in Figure B.4.

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Figure B.4. Typical Drum Dryer, Double Drum
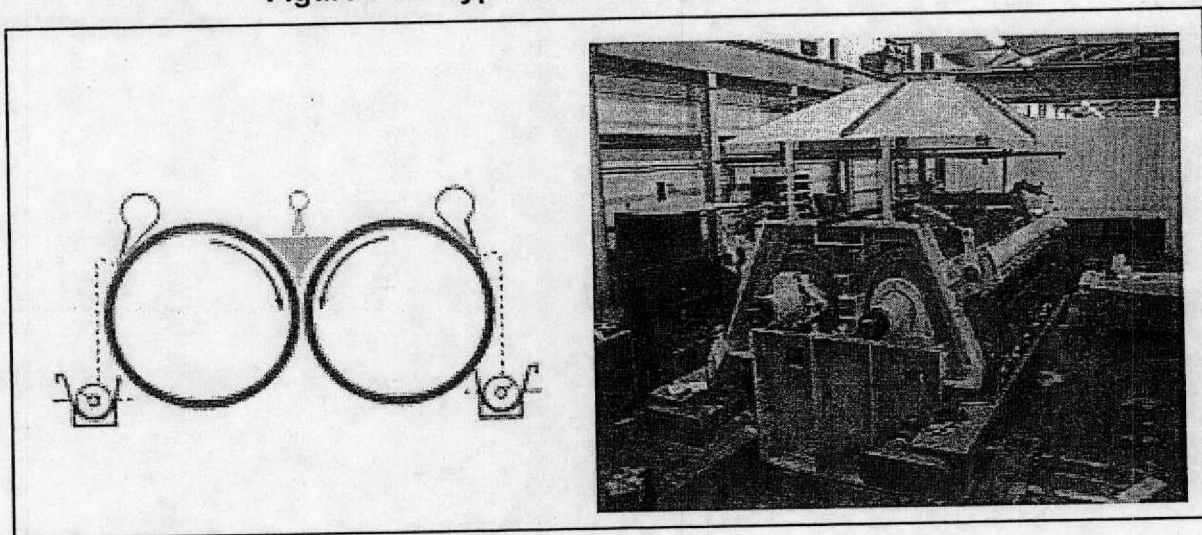
The material to be dried is pumped, either directly or through spray nozzles, into the nip formed between two drying drums. The thickness of the product film may be varied by adjustment of the gap between the drying drums or cylinders (*Drum Dryer Information Web Page* [Simon 2004b]).

Liquid is fed from a trough or perforated pipe into a pool in the space above and between the two rollers. The pool is confined by stationary end plates. Heat is transferred by conduction to the liquid that is partly concentrated in the space between the rollers. Concentrated liquid discharges from the bottom of the pool as a viscous layer covering the remainder of the drum surface. Substantially all the liquid is vaporized from the solid as the drums turn, leaving a thin layer of dry material to be scraped off by doctor blades into conveyors below. Vaporized moisture is collected and removed through a vapor head above the drums.

Double-drum dryers are effective with dilute solutions, concentrated solutions of highly soluble materials, and moderately heavy slurries. They are not suitable for solutions of salt with limited solubility or for slurries of abrasive solids that settle out and create excessive pressure between the drums (McCabe 1985).

The rollers of a drum dryer are 2 to 10 ft (0.6 to 3 m) in diameter and 2 to 14 ft (0.6 to 4.3 m) long. The solid is in contact with the hot metal for 6 to 15 seconds, which is short enough to result in little decomposition of even heat sensitive products. Drying capacity is proportional to the active drum area, and is usually between 1 and 10 lb of dry material 1 ft^2 of drying surface per hour (5 and 50 kg/m^2 per hour) (McCabe 1985). Table B.4 summarizes key parameters of typical drum dryer application.
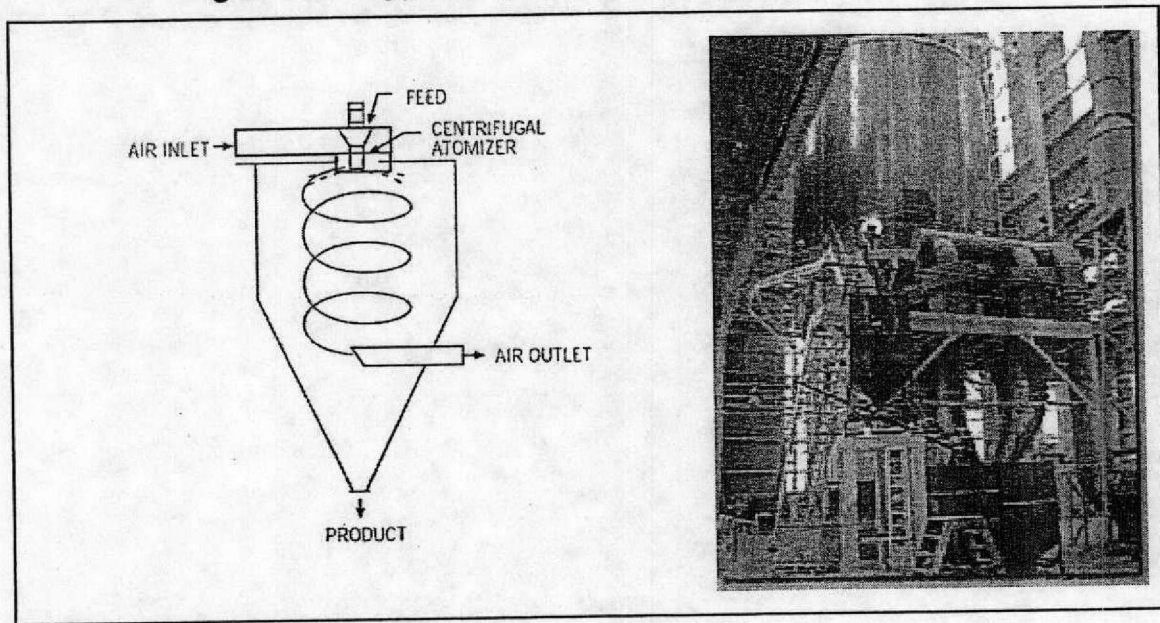
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Table B.4. Typical Drum Dryer Application

Application:	Drying solutions and slurries
Waste Application:	No salt or brine waste examples found
Application Similar to ETF Brine:	No similar applications found
Feed Material Weight % Solids:	2 to 80
Feed Rates:	No similar feeds for comparison
Dimensions:	2 to 10 ft (0.6 to 3 m) in diameter, 2 to 14 ft (0.6 to 4.3 m) in length*
Temperatures:	212 to 240 °F (100 to 116 °C)

*Source: McCabe 1985.

B5.0 SPRAY DRYER

A spray dryer disperses a slurry or liquid into a stream of hot gas in the form of a mist of fine droplets (Figure B.5). The liquid is converted into a fog-like mist (atomized), providing a large surface area. The atomized liquid is exposed to a flow of hot air in a drying chamber. The moisture evaporates quickly and solids are recovered as a powder consisting of fine, hollow, spherical particles. Feed stream material is suspended in air that is normally moved upwards and countercurrent to the feed stream. Spray dryers use air inlet temperatures of up to 482 °F (250 °C) or higher (depending on type of product), but because of evaporation the outlet temperature of the air decreases rapidly to a temperature of about 203 °F (95 °C).

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Figure B.5. Typical Spray Dryer, Diagram and Picture

The product temperature will be 68 to 86 °F (20 to 30 °C) below the air outlet temperature. Heating of the drying air can be accomplished by steam or by direct gas-fired air heaters, or indirect heaters fired by gas, liquid, or solid fuels. Exhaust air is passed through cyclones to recover particulate material (dust) that is carried over in the exhaust air as an integral part of the process. Recovered material is incorporated back in the product.

Droplets are formed inside a cylindrical drying chamber by pressure nozzles and two-fluid nozzles, or in large dryers by high-speed spray disks. The drying chambers are large (e.g., 8 to 20 ft [2.5 to 9 m]) to prevent droplets, or wet solid particles, from striking solid surfaces before drying has occurred.

Spray dryers are controlled by programmable logic controllers (PLCs) or solid-state controllers. In spray drying systems, exhaust air temperature or humidity provides an input signal that, by way of a setpoint, will modulate the energy supplied to the process. Mechanically, these dryers are relatively low-maintenance units. They can be fabricated from materials ranging from basic carbon steel to sophisticated duplex stainless steel. These dryers must be fully insulated to allow energy-efficient operation. Tall-form dryers have a pump and exhaust fan requiring differing amounts of maintenance, depending on service, environment, and abrasion characteristics of the product. Nozzle deterioration (specifically, the orifice plates) may require frequent replacement due to the deterioration adversely affecting the spray pattern. ("Spray Dryers, A Review of Major Dryer Types, Part 2" [Traub 2001c]).

Spray dryers are extremely energy intensive and have a correspondingly high operating cost, since more moisture is being thermally evaporated from the feed than in most other types of dryers. It is more expensive to thermally evaporate moisture than to mechanically dewater. Many spray dryers have problems involving product buildup on the dryer walls. In some instances, this buildup can add additional load to the tower, stressing the structure (Traub 2001c).

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Spray dryers have a unique position in the arena of thermal drying. There is no other high-volume method for producing a free-flowing powder from a liquid in one step. They offer unique, unmatched versatility in powder production and can control powder characteristics to a specified requirement (Traub 2001c).

The chief advantage of spray dryers are their very short drying time, which permits drying of highly heat sensitive materials and production of solid or hollow spherical particles. The desired consistency, bulk density, appearance, and flow properties of some products (e.g., foods or synthetic detergents) may be difficult or impossible to obtain in any other type of dryer.

Spray dryers also have the advantage of yielding a dry product that is ready for packaging from a solution, slurry, or thin paste, in a single step. A spray dryer may combine functions of an evaporator, a crystallizer, a dryer, a size-reduction unit, and a classifier. Systems that can utilize a spray dryer may be able to considerably simplify the overall process (McCabe 1985).

Spray dryers are not highly efficient when considered as dryers alone because heat is lost in the discharge gases. They are bulky and very large (often 24 m [80 ft] or more high) and not always easy to operate. Table B.5 summarizes key parameters of typical spray dryer application.

Table B.5. Typical Spray Dryer Application

Application:	Drying solutions
Waste Application:	No similar waste applications found
Application Similar to ETF Brine:	No similar applications found
Feed Material Weight % Solids:	5 to 60
Feed Rates:	No similar waste feed found for comparison
Dimensions:	2.4 to 6 m (8 to 20 ft) in diameter
Temperatures:	1200 °F (649 °C)

B6.0 PULSE DRYER

A pulse drying system has two sources of energy to evaporate a water and solids feed stream by using sound pressure waves to atomize the raw feed and the heat value from the fuel consumed to evaporate the water. This results in evaporating the water fraction in a single pass in less than a second and leaving the solids in a dry state in the collector. The exposure of the raw feed stream is measured in milliseconds resulting in less British thermal units (Btu) consumed to remove a pound of water with the exit temperature of the solids measured from 125 to 150 °F (52 to 66 °C), which results in less equipment requirements for offgas exhaust scrubbing and treatment.

The drying takes place in an extension of a pulse combustion burner, which is a an aerodynamically designed hollow tube made of a steel alloy whose shape dictates the frequency

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that is generated, as shown in Figure B.6. The detonations create a pressure wave that is transformed into a 250 Hertz wave form as well as creating a heat value ranging from 2000 to 2500 °F (1093 to 1371 °C) for evaporation. These two sources of energy are created by the burning of a liquid or gaseous fuel, which simultaneously creates pressure waves for atomization and heat for evaporation.

Figure B.6. Typical Pulse Dryer
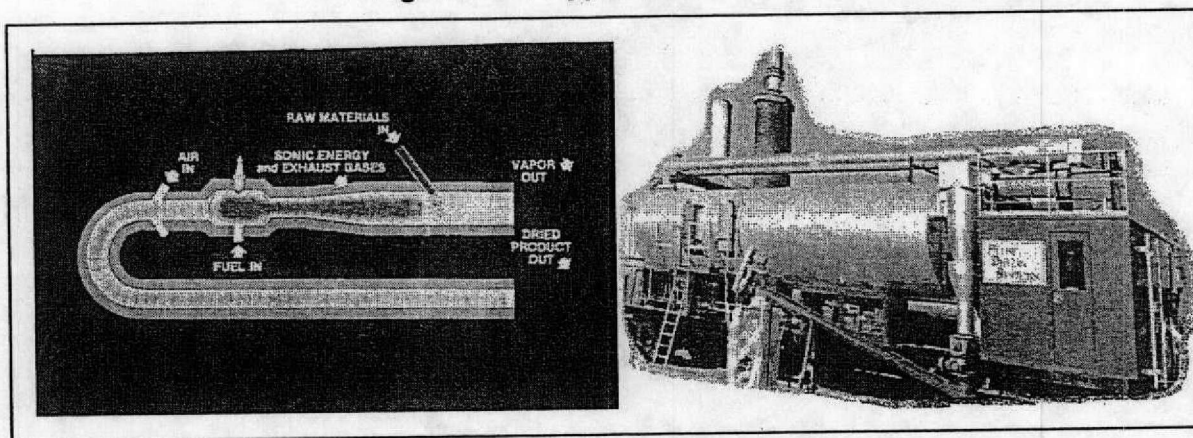
Raw feed streams ranging from 1% solids to 99% solids can be fed into the pulse dryer. Actual drying can take place from 3 to 5 minutes from a cold system start and the system can be used as a batch or continuous dryer and minimal system oversight is needed as the system begins it production-drying activity.

Pulse drying is a relatively new technology, but it has successfully tested over 200 raw feed materials in the pulse dryer since 1980 and has concentrated on providing drying services to industry for the effluent coming from a wide variety of waste streams including hazardous wastes. Pulse dryer waste streams have included the following:

- Drying hazardous metal oxide plating wastes
- Radioactive depleted uranium wastewater stream
- Sodium sulfate
- Ammonium sulfate
- Calcium chloride.

Pulse drying systems offer the following advantages:

- Energy competitive

- Require less downtime

- Need less equipment maintenance

- Have all automatic control features requiring only one person per shift to be in attendance

- Result in fewer emission concerns going to air filters or scrubbers

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- Have moving parts, resulting in less wear items to be replaced and final disposal costs at the end of the project greatly reduced because of the fewer contaminated services to be dealt with.

Pulse dryers have relatively moderate levels of entrained solids is the exhaust streams, and typically require dedicated exhaust systems. However adjustment can be made to reduce the amount of entrained solids by slightly increasing the final moisture content and reducing dusting. Table B.6 summarizes key parameters of typical pulse dryer application.
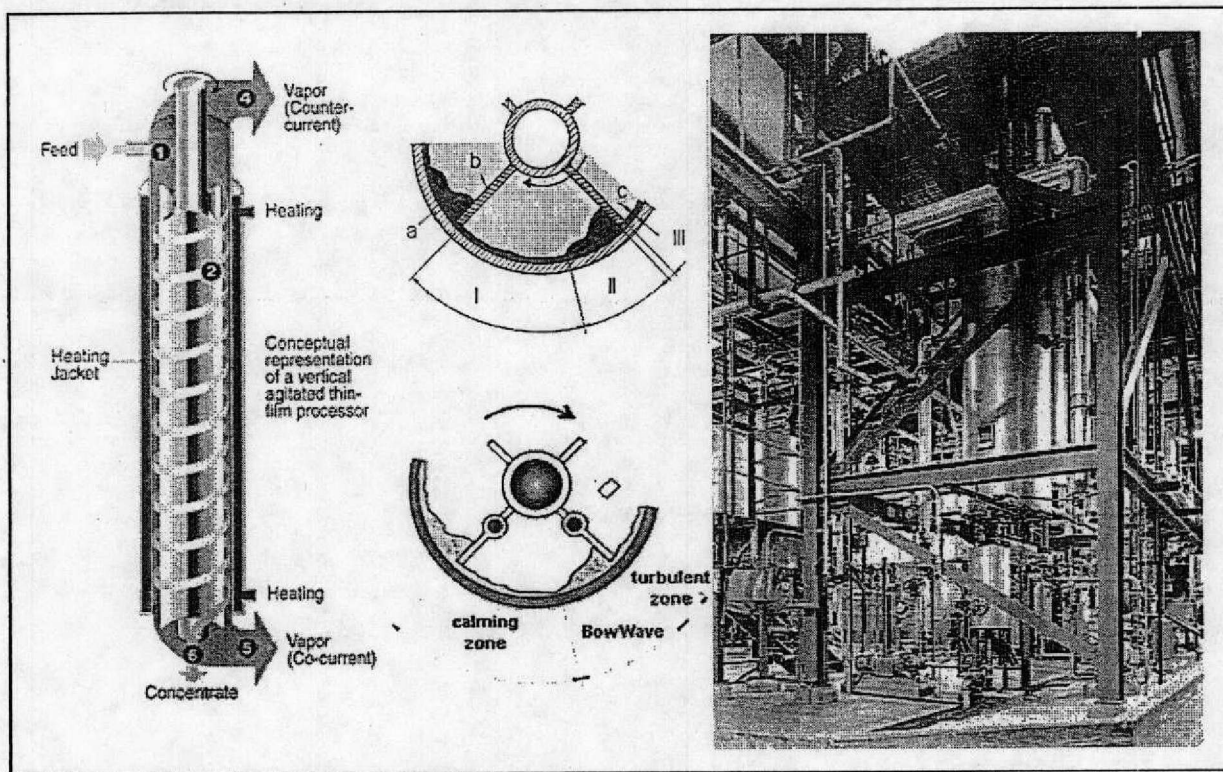
Table B.6. Typical Pulse Dryer Application

Application:	Drying solutions, slurries, and solids
Waste Application:	Diverse including brine, mixed and radioactive wastes
Application Similar to ETF Brine:	Similar brines and similar hazards
Feed Material Weight % Solids:	1 to 99
Feed Rates:	23 to 38 L (6 to 10 gal) per minute
Dimensions:	10- to 15-ft- (3- to 5-m-) diameter, 30 to 45 ft (10 to 15 m) long
Temperatures:	Pulse 2000 to 2500 °F (1093 to 1371 °C); exit 125 to 150 °F (52 to 66 °C)

B7.0 THIN-FILM DRYER (MODIFICATIONS AND NEW SYSTEMS)

Thin-film dryers feed liquids or slurries into a cylindrical, heated dryer body where rotary wiper blades spread the feed material across the heated internal walls as a thin film. Turbulent flow in the thin film, created by the wiper blades, dramatically increases the heat transfer from the heating body to the surface area of the feed. Agitation created in the bow wave of the wiper blades (shown in Figure B.7) ensures particulate suspension, thus reducing agglomeration of solids and ensures consistent heating of the waste product.

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Figure B.7. Typical Thin-Film Dryer (vertical) Diagram and Picture

The blades also mechanically mobilize solids created in the drying process. The wetted area of the dryer heating body surface is optimized by the wiper blade gap dimension. This provides an inherent flexibility of 20 to 100% design feed flow for some models. In some dryers, the wiper blades are adjustable to increase flexibility in process feed flow rate and viscosity. Heat for the drying process is conducted to the drying surface from either an outer shell or direct electrical heating. Any hot gas or hot liquid source can be utilized if a tube in a shell heat transfer method is used. The thermal efficiency of agitated thin-film dryers is high, and there is little loss of solid particulates because little or no gas is required to be drawn through the unit. Vacuum or low-velocity ventilation is used to remove offgases from this dryer.

Agitated thin-film dryers achieve a high evaporative efficiency and operate in a substantial range of processes, temperatures, viscosities, and residence times. This dryer method for removing dry waste product from liquid or slurry waste feed can be accomplished in a one-stage, continuous process. The dryer discharges a flow-able solid for disposal.

There are two basic types of thin-film dryers. The one described in this section is a vertical dryer that is primarily used in less sensitive feeds, not requiring long residence times and uses gravity and mechanical agitation to transport the feed through the process. The second dryer is a horizontal dryer and is commonly used for feeds with higher temperature sensitivity and for reactor processes that require a higher residence time. Horizontal dryers may also be used where head space is insufficient for a vertical dryer. Additional residence time can be designed into either dryer using centrifugal effects generated by a conical dryer body.

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Thin-film dryers compete with spray dryers as systems that can accept liquid or slurry feed, and produce a dry, free-flowing solid product. They are normally built in two sections; the first being a vertical agitated evaporator dryer, and the second being a horizontal dryer with an internal auger in which residual liquid content of the material is reduced to the desired level. The vertical section removes most of the water from the feed stream and discharges a partially wet solid to the second section.

A variety of agitated thin-film dryers are commercially available in both vertical and horizontal configurations. They are available with cylindrical or tapered heating surface bodies and wiper blades to facilitate design optimization with respect to waste product evaporation rate and feed distribution on the heating body surface. This type of dryer is highly flexible and optimal for converting liquid and slurry waste products into a flow-able solid waste. This dryer is more expensive than other dryers, but has the advantage of not plugging or jamming, and produces a uniform solid waste product.

Agitated thin-film dryers take advantage of the efficiencies of other tube evaporators (e.g., rising and falling film evaporators) but without operating problems associated with the following:

- Product plugging or fouling of the drying surface
- Low heat transfer coefficients due to higher air flow and near laminar film flows
- High-pressure drops at product discharge due to high product viscosities.

This system is relatively expensive, but is highly configurable to provide flexibility to handle various feeds. Most liquid waste feeds can be processed at a rate of between 20 to 40 lb/ft^2 (100 to 200 kg/m^2) per hour and are dependent upon the dryer size. Typical feed in weight percent is highly variable. For a waste stream with very low weight percent solids, a multi-stage dryer can be used for a very high weight percent solids output waste form. This is the equivalent of pre-treating the waste product with an evaporator. Most liquids can be removed from a waste feed with about 20 wt% by weight in one stage down to about 95 wt% solids.

A commercially available dryer with 2 m^2 22 ft^2 of surface area is 710 mm (28 in.) in diameter and 3,530 mm (139 in.) tall. Another brand has 2.3 m^2 (25 ft^2) of surface area and is 457 mm (18 in.) in diameter and 3,658 mm (144 in.) tall. This commercially available dryer is offered in sizes between 0.2 and 26 m^2 (2 and 275 ft^2) of surface area. This yields from about 40 to 11,000 lb (18 to 4,990 kg) per hour in achievable process flow rate.

The thermal efficiency of thin-film dryers is high, and there is little loss of solids, since little or no gas is required to be drawn through the unit. Thin-film dryers are useful in removing and recovering solvents from solid products. They are relatively expensive and are somewhat limited in heat transfer area. With both aqueous and solvent feeds the acceptable feed rates are usually between 20 to 40 lb/ft^2 (100 to 200 kg/m^2) per hour. Table B.7 summarizes key parameters of typical thin-film dryer application.

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Table B.7. Typical Thin-Film Dryer Application

Application:	Drying solutions and pumpable slurries
Waste Application:	Volume reduction of salts
Application Similar to ETF Brine:	ETF STT thin film dryer
Feed Material Weight % Solids:	2 to 60
Feed Rates:	20 to 100,000 kg (44 to 220,462 lb) per hour
Dimensions:	46 cm (18 in). in diameter, 4 m (12 ft) tall (0.7 m^3 [25 ft^3] unit)
Temperatures:	212 to 240 °F (100 to 116 °C)

B8.0 REFERENCES

CIAA, 2002, Best Available Techniques reference document, Position Paper, CIAA AISBL Confederation of the Food and Drink Industries in the EU.

McCabe Smith Harriott, 1985, Unit Operations of Chemical Engineering, 4th Edition, New York, New York.

Simon, 2004a, *Rotary Dry Information Web Page*, http://www.simon-dryers.co.uk, R. Simon (Dryers) LTD, Nottingham, England.

Simon, 2004b, *Drum Dryer Information Web Page*, http://www.simon-dryers.co.uk, R. Simon (Dryers) LTD, Nottingham, England.

Traub, D., 2001a, "Flash Drying," *Process Heating, Dryer Files*, http://www.Process-Heating.com.

Traub, D., 2001b, "Fluid Bed Dryers," *Process Heating, Dryer Files*, http://www.Process-Heating.com.

Traub, D., 2001c, "Spray Dryers, A Review of Major Dryer Types, Part 2," *Process Heating, Dryer Files*, http://www.Process-Heating.com.

Traub, D., 2002, "A Review of Major Dryer Types, Rotary Dryers, Part 3," *Process Heating, Dryer Files*, http://www.Process-Heating.com.

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APPENDIX C
SCREENING EVALUATION FOR DRYER ALTERNATIVES

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1. New Rotary Dryer in Parallel with Current Dryer

Option Description: A 15 L/min (4 gal/min) rotary dryer would be installed in parallel with the current thin-film dryer, allowing either one to be selected from the control room during an STT operating evolution. A larger-capacity dryer is required to compensate for fouling expected on the feed end of the dryer. The piping and dry material handling system would be modified to allow parallel operation of the dryers; otherwise, no major process changes would be implemented.

Ability to Accept Liquid/Solution Feeds: 1

Rotary dryers are not designed for drying liquids. The process mixes particulate and brings wet particles into contact with dry particles and the baffled interior of the dryer. Contact of liquids with dryer particulates will form agglomerate, and contact with the baffled interior will form build-up throughout the dryer. Drying media can be added to the feed and then collected as dried-material for reuse, but the need for solids segregation and recycle makes this technique an unattractive compensation for a system not designed to handle liquid feeds.

Ability to Accept Slurry Feeds: 1

Rotary dryers are not designed for drying slurries. The rotating/tumbling process mixes particulate and brings wet particles in contact with dry particles and the baffled interior of the dryer. Contact of slurries with dryer particulates will form agglomerate, and contact with the baffled interior will form build-up throughout the dryer. Drying media can be added to the feed and then collected as dried-material for reuse, but the need for solids segregation and recycle makes this technique an unattractive compensation for a system not designed to handle slurry feeds.

Thermal Efficiency: 3

Rotary dryers waste little heat in the exhaust gas and impart a high percentage of the energy expended to the feed material; however, the large size of a typical rotary dryer results in significant heat loss throughout the body of the rotating cylinder. The large size of a typical rotary dryer also commonly results in outdoor installation, resulting in further losses of heat in cold or windy environments.

Thermal efficiency for liquid or slurry brine solutions will be further reduced by scaling and buildup on the feed end of the dryer to an extent rendering it virtually ineffectual.

Loss of Solids (dusting/air entrainment): 4

Rotary dryers have low air velocity and are excellent at agglomerating feed material, which results in a low loss of solids. However, a high buildup of solids on the interior surfaces of a rotary dryer is likely if the expected feed stream is a liquid or slurry.

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Air Exhaust Rate: 5

Rotary dryers only require minimal airflow to vent saturated vapors and introduce new dry air. Rotary dryers would likely produce low volumes of fully saturated air, which is optimal for the ETF STT.

Free Flowing Product: 2

Rotary dryers typically produce a free-flowing product; however, the expected feed stream will likely agglomerate into larger masses and flow poorly. It may be possible to extend the length of drying past the point when sufficient drying is achieved, and use the larger masses to break each other down into a more fluid consistency, but this would be an additional expense in capital and operating costs.

Ease in Maintenance: 1

Rotary dryers are simple to maintain, requiring more brute force than technical precision. However, the expected feed stream would be problematic to operate, resulting in a high rate of maintenance evolutions. These evolutions would generally be internal cleanouts of radioactive and hazardous waste from the internal baffles of the rotating cylinder.

Ease in Operations: 1

Rotary dryers can be problematic when there are variances in a feed stream containing fouling agents; however, this problem is overshadowed by the low percentage of solids in the feed stream. The expected feed stream is likely to result in high buildup of solids on the interior surfaces of a rotary dryer. Drying media can be added to the feed, and then collected as dried material for reuse, but the need for solids segregation and recycle makes this technique an unattractive compensation for a system not designed to handle liquid feeds.

Overall Applicability to this Process: 2.25

The overall applicability score is based on an un-weighted average of the individual screening criteria scores. Based on this evaluation fluidized-bed drying technology is not recommended for further consideration.

2. New Fluidized-Bed Dryer in Parallel with Current Dryer

Option Description: A 4 gal/min fluidized-bed dryer would be installed in parallel with the current thin-film dryer, allowing either one to be selected from the control room during an STT operating evolution. A larger capacity dryer is required to compensate for fouling expected on the walls of the dryer. The piping and dry material handling system would be modified to allow parallel operation of the dryers; otherwise, no major process changes would be implemented.

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Ability to Accept Liquid/Solution Feeds: 1

Fluidized-bed dryers are not designed for drying liquids. The process violently mixes particulate and brings wet particles in contact with dry particles and the wall of the dryer. Contact of liquids with dryer particulates will form agglomerate, and contact with the wall of the dryer will form build-up on the walls. Drying media can be added to the feed and then collected as dried material for reuse. However, the need for solids segregation and recycle makes this technique an unattractive compensation for a system not designed to handle liquid feeds.

Ability to Accept Slurry Feeds: 2

Fluidized-bed dryers are not designed for drying slurries. The process violently mixes particulate and brings wet particles in contact with dry particles and the wall of the dryer. Contact of slurries with dryer particulates will form agglomerate, and contact with the wall of the dryer will form build-up on the walls. Drying media can be added to the feed, and then collected as dried-material for reuse. However, the need for solids segregation and recycle makes this technique an unattractive compensation for a system not designed to handle liquid feeds.

Thermal Efficiency: 3

The exhaust gas flow rates from a fluidized-bed dryer are significant and carry most of the heat out when they exit the system, giving the system a low overall heat efficiency. Heat transfer is efficient due to mixing and surface area per volume of solution, but high air flow rate used to maintain bed fluidization results in a low residence time for heated air.

Loss of Solids (dusting/air entrainment): 1

Fluidized-bed dryers can have significant dry material carry-over into the exhaust gas system, which must be separated and returned to the solids stream. Solids carry-over can be compounded if dry materials are broken down by collision in the fluidized-bed into small particles that are easily entrained. Significant solids carry-over typically requires additional bulky but inexpensive equipment. The maintenance of this equipment can be more expensive than the initial capital cost if the solids are hazardous.

Air Exhaust Rate: 1

Fluidized-bed dryers have the highest volumes of exhaust gas of all technologies evaluated. The exhaust gas systems require solids separators and are typically not combined with other facility HVAC systems that have significantly less entrained solids. Therefore, fluidized-bed dryers typically require dedicated exhaust systems.

Free Flowing Product: 5

No drying system is more suitable for producing free-flowing solids. Fluidized-bed dryers are designed to produce dry free-flowing solids. However, the brine solution anticipated as

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feed would have to be supplemented with drying media to prevent agglomeration and salt build-up on the dryer walls.

Ease in Maintenance: 1

The lack of moving parts contacting the process stream would normally result in minimum required maintenance; however, operational problems associated with a liquid feed will result in frequent fouling of the internal walls of the bed. Variances in feed stream can be problematic for a spray dryer to control operationally and can cause increased required maintenance.

Ease in Operations: 1

The chaotic mixing inside a fluidized bed dryer makes it impossible operationally to segregate the dry particulates from the suspended liquids and prevent the solutions and sticky particles from contacting the walls of the dryer. Contact of liquids with dryer particulates will form agglomerate, and contact with the wall of the dryer will form build-up on the walls. Drying media can be added to the feed and then collected as dried-material for reuse. However, the need for solids segregation and recycle makes this technique an unattractive compensation for a system not designed to handle liquid feeds.

Fluidized-bed dryers require a highly-automated rapidly-reacting control system to operate efficiently. Variances in feed stream can be problematic for a fluidized-bed dryer to control operationally.

Overall Applicability to this Process: 1.88

The overall applicability score is based on an un-weighted average of the individual screening criteria scores. Based on this evaluation, fluidized-bed drying technology is not recommended for further consideration.

3. New Flash Dryer in Parallel with Current Dryer

Option Description: A 3 gal/min flash dryer would be installed in parallel with the current thin-film dryer, allowing either dryer to be selected from the control room during an STT operating evolution. A larger capacity dryer is required to compensate for fouling expected on the feed end of the dryer. The piping and dry material handling system would be modified to allow parallel operation of the dryers; otherwise, no major process changes would be implemented.

Ability to Accept Liquid/Solution Feeds: 1

Flash dryers are not designed for drying liquids. A flash dryer accepting a liquid feed would constantly splatter wet particles against the internal surfaces of the dryer. Contact of liquids with the dryer wall will form build-up on the walls. Drying media can be added to the feed, and then collected as dried-material for reuse. However, the need for solids segregation and recycle makes this technique an unattractive compensation for a system not designed to handle liquid feeds.

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Ability to Accept Slurry Feeds: 1

Flash dryers are not designed for drying slurries. A flash dryer accepting slurry feed would constantly splatter wet particles against the internal surfaces of the dryer. Contact of liquids with the dryer wall will form build-up on the walls. Drying media can be added to the feed, and then collected as dried material for reuse. However, the need for solids segregation and recycle makes this technique an unattractive compensation for a system not designed to handle liquid feeds.

Thermal Efficiency: 4

The exhaust gas flow rates from a flash dryer are significantly less than that of a fluidized-bed dryer, because feed material is only fluidized in short intervals. Exhaust gases carry a portion of heat when they exit the system reducing the systems overall heat efficiency, but the exhaust gas is more efficiently utilized, and saturated, then the exhaust gases from spray dryers or fluidized bed dryers. Heat transfer is efficient due to mixing and surface area per volume of solution.

Loss of Solids (dusting/air entrainment): 1

Flash dryers can have significant dry material carry-over into the exhaust gas system that must be separated and returned to the solids stream. Solids carry-over can be compounded if dry materials are broken down by collisions during the high-velocity high-impact flashing process. Once the drying material is broken down into small particles, they are entrained. Significant solids carry-over typically requires additional bulky but inexpensive equipment. Maintenance of this equipment can be more expensive than the initial capital cost if the solids are hazardous.

Air Exhaust Rate: 3

Exhaust gas flow rates from a flash dryer are significantly less than that of a fluidized-bed dryer, because the feed material is only fluidized in short intervals. Exhaust gas systems require solids separators and are typically not combined with other facility HVAC systems that have significantly less entrained solids. Therefore, flash dryers typically require dedicated exhaust systems.

Free Flowing Product: 2

Few drying systems are more suitable for producing free-flowing solids. Flash dryers are designed to produce near-dry or dry free-flowing solids. However, the brine solution anticipated as feed would have to be supplemented with drying media to prevent agglomeration and salt build-up on the dryer walls.

Ease in Maintenance: 4

Fouling and blockage are a common problem for flash dryers. Loss of power to the dryer will cause the product to fall out of suspension and build up in the dryer base and feed throat. If the product hardens under heat, blockage may occur that requires significant time to

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remove. Due to the relatively high velocities, the particle size may be reduced due to attrition and impact. High velocities also may contribute to premature component wear if the system is not designed to inhibit it.

While parts are cheap, the labor is significant. Maintenance is almost exclusively devoted to internal parts in close proximity to hazardous and radioactive materials.

Ease in Operations: 2

Flash dryers are relatively easy to operate if the feed is consistent. Inconsistent feeds can cause fouling and blockage, which in turn alter the flow characteristic on the flash dryer, making them even more difficult to control. Flash dryers are not designed for a liquid feed; any method to compensate for the use of a liquid feed will complicate the process and make operation more difficult.

Overall Applicability to this Process: 2.25

The overall applicability score is based on an un-weighted average of the individual screening criteria scores. Based on this evaluation, fluidized-bed drying technology is not recommended for further consideration.

4. New Pulse Dryer in Parallel with Current Dryer

Option Description: A 7 L/min (2 gal/min) pulse dryer would be installed in parallel with the current thin-film dryer, allowing either dryer to be selected from the control room during an STT operating evolution. The piping and dry material handling system would be modified to allow parallel operation of the dryers; otherwise, no major process changes would be implemented.

Ability to Accept Liquid/Solution Feeds: 5

No drying system is more suitable for drying solutions. Pulse dryers are designed for liquid feeds, and cannot produce dry free-flowing solids. The nozzles feeding the pulse chamber tend to operate more efficiently and require less maintenance for solutions with low viscosity, low suspended solids content, and low abrasive content.

Ability to Accept Slurry Feeds: 4

Few drying systems are more suitable for drying slurries. Pulse dryers are designed for liquid and light slurry feeds. The nozzles feeding the pulse chamber tend to operate more efficiently and require less maintenance for solutions with low viscosity, low suspended solids content, and low abrasive content.

Thermal Efficiency: 5

Exhaust gas flow rates from a pulse dryer are significantly less than that of a fluidized-bed dryer because the feed material is only fluidized in short intervals. Exhaust gases carry a portion of the heat when they exit the system reducing the systems overall heat efficiency.

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However, the exhaust gas is more efficiently utilized and saturated then the exhaust gasses from spray dryers or fluidized bed dryers. Heat transfer is efficient due to mixing and surface area per volume of solution.

Loss of Solids (dusting/air entrainment): 3

Pulse dryers can have significant dry material carry-over into the exhaust gas system, which must be separated and returned to the solids stream. This typically requires additional equipment. Maintenance of this equipment, including filer media, is more expensive then the initial capital cost if the solids are hazardous.

Air Exhaust Rate: 2

Pulse dryers have significant volumes of exhaust gas. Exhaust gas systems may require solids separators and are typically not combined with other facility HVAC systems that have significantly less entrained solids. Therefore, pulse dryers typically require dedicated exhaust systems.

Free Flowing Product: 5

Few drying systems are more suitable for producing free-flowing solids. Pulse dryers are designed for liquid feeds and to produce dry powdery free-flowing solids.

Ease in Maintenance: 4

The lack of moving parts that contact the process stream results in minimum required maintenance. The sprayer requires replacement when worn and cleanout when clogged, but the spray nozzle assembly is normally removable from outside the vessel and easily maintained. Variances in feed stream can be problematic for a pulse dryer to control operationally and can cause increased required maintenance.

Ease in Operations: 3

Variances in feed stream can be problematic for a pulse dryer to control operationally.

Overall Applicability to this Process: 3.88

The overall applicability score is based on an un-weighted average of the individual screening criteria scores.

5. New Spray Dryer in Parallel with Current Dryer

Option Description: A 7 L/min (2 gal/min) spray dryer would be installed in parallel with the current thin-film dryer, allowing either one to be selected from the control room during an STT operating evolution. A slightly larger capacity dryer is required to compensate for fouling expected on the walls of the dryer. The piping and dry material handling system would be modified to allow parallel operation of the dryers; otherwise, no major process changes would be implemented.

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Ability to Accept Liquid/Solution Feeds: 5

No drying system is more suitable for drying solutions. Spray dryers are designed for liquid feeds and to produce dry powdery free-flowing solids. Spray nozzles tend to operate more efficiently and require less maintenance for solutions with low viscosity, low suspended solids content, and low abrasive content.

Ability to Accept Slurry Feeds: 4

Spray dryers are suitable for most slurries. However, spray nozzles tend to operate more efficiently and require less maintenance for solutions with low viscosity, low suspended solids content, and low abrasive content.

Thermal Efficiency: 3

Exhaust gases from a spray dryer are significant and carry most of the heat when they exit the system. Heat transfer is efficient due to surface area per volume of solution, but air flow must be maintained at a high velocity to ensure the solids are dry before contacting the walls of the dryer, as to avoid build-up on the walls.

Loss of Solids (dusting/air entrainment): 2

Spray dryers can have significant dry material carry-over into the exhaust gas system, which must be separated and returned to the solids stream. Typically this requires additional bulky but inexpensive equipment. Maintenance of this equipment is more expensive than the initial capital cost if the solids are hazardous.

Air Exhaust Rate: 2

Spray dryers have significant volumes of exhaust gas only exceeded by fluidized beds. Exhaust gas systems require solids separators and are typically not combined with other facility HVAC systems that have significantly less entrained solids. Therefore, spray dryers typically require dedicated exhaust systems.

Free Flowing Product: 5

No drying system is more suitable for producing free-flowing solids. Spray dryers are designed for liquid feeds and to produce dry powdery free-flowing solids.

Ease in Maintenance: 4

The lack of moving parts that contact the process stream results in minimum required maintenance. The sprayer requires replacement when worn and cleanout when clogged, but the spray nozzle assembly is normally removable from outside the vessel and easily maintained. Variances in feed stream can be problematic for a spray dryer to control operationally and can cause increased required maintenance.

Ease in Operations: 2

Variances in feed stream can be problematic for a spray dryer to control operationally.

Overall Applicability to this Process: 3.38

The overall applicability score is based on an un-weighted average of the individual screening criteria scores.

6. New Drum Dryer in Parallel with Current Dryer

Option Description: A 7 L/min (2 gal/min) drum dryer would be installed in parallel with the current thin-film dryer, allowing either one to be selected from the control room during an STT operating evolution. The piping and dry material handling system would be modified to allow parallel operation of the dryers; otherwise, no major process changes will be implemented.

Ability to Accept Liquid/Solution Feeds: 3

Drum drying systems are designed exclusively for solutions and slurries, but are not suited for brine solidification application because of the projected dissolved and suspended solids. Drum dryers are problematic for salt solutions, abrasives, and sticky material. ETF brine salts can exhibit all of these problematic properties in various degrees. Low solubility salts (i.e., carbonates) that fall out of solution in the pool of liquid above the drums can cause adverse pressure between drums as they are forced between them as solids. Abrasive hard scaling salts (i.e., carbonates and nitrates) can damage scrappers and cause a continuous maintenance problem. Sticky salts (i.e., nitrates) are problematic at all shear points on drum mixers.

Ability to Accept Slurry Feeds: 2

Drum drying systems are designed exclusively for solutions and slurries, but are not suited for brine solidification application because of the projected dissolved and suspended solids. Drum dryers are problematic for salt solutions, abrasives, and sticky material (see Ability to Accept Liquid/Solution Feeds).

Thermal Efficiency: 4

Drum dryers waste little heat in exhaust gas, and impart a high percentage of the energy expended to the feed material. Scaling only becomes an issue when the scraping blade becomes damaged from use.

Loss of Solids (dusting/air entrainment): 4

Drum dryers have virtually no air entrainment, though minimal dust may be caused at the scrapper blade or auger collection systems typical to drum dryers. Drum dryers do not require substantial air flow; therefore, the air velocities, and correspondingly the air entrainment, are minimal. Dried material is scraped off the drum as sheets or flakes, and

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then pulverized by the auger collection system to create a free-flowing solid. The process can cause dust, but auger rate adjustments can yield the desired sizes without excess dust generation.

Air Exhaust Rate: 5

Drum dryers require only minimal air flow for efficient operation. Saturated moist air is lightly drawn away from the dryer by an exhaust fan. The air velocities, and correspondingly the air entrainment, are minimal. Drum dryers can feed exhaust air directly to the facility air handling systems after the moisture is condensed out.

Free Flowing Product: 2

Drum dryers do not produce a free-flowing product without the addition of a pulverizing system. However, a dry product removal system, such as an auger, inherently pulverizes the product. Dried material is scraped off the drum as sheets or flakes, which falls into the auger collection system and is pulverized to create a free-flowing solid. Pulverization can cause dust, but auger rate adjustments can yield the desired sized without excess dust generation.

Ease in Maintenance: 1

Drum dryers are problematic for salt solutions, abrasives, and sticky material. ETF brine salts can exhibit all of these problematic properties in various degrees (see ability to accept liquid feed section above for details). The drum dryer also has moving, shearing, and abrading parts that are in contact with the contaminated feed stream. It is anticipated that most maintenance operations would involve work on contaminated components. Variances in feed stream can be problematic for a drum dryer to control operationally and can cause increased required maintenance.

Ease in Operations: 2

Variances in feed stream can be problematic for a drum dryer to control operationally.

Overall Applicability to this Process: 2.88

The overall applicability score is based on an un-weighted average of the individual screening criteria scores. Based on this evaluation, drum dryer technology is not recommended for further consideration.

7. New Thin-Film Dryer in Parallel with Current Dryer

Option Description: A 1.8 gal/min thin-film dryer would be installed in parallel with the current thin-film dryer, allowing either one to be selected from the control room during an STT operating evolution. The piping and dry material handling system would be modified to allow parallel operation of the dryers; otherwise, no major process changes would be implemented.

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Ability to Accept Liquid/Solution Feeds: 5

No drying system is more suitable for drying solutions. Thin-film dryers are designed for liquid and pumpable slurry feeds and are capable of producing free flowing solids.
The blades of wipers can be catered to specific feeds, as detailed in Appendix D. Most configurations are robust enough to tolerate variable feeds. However, major feed stream modifications may require a change in the blade of wiper system being employed.

Ability to Accept Slurry Feeds: 5

No drying system is more suitable for drying solutions. Thin-film dryers are designed for liquid and pumpable slurry feeds, and are capable of producing free flowing solids.

Thermal Efficiency: 4

Thin-film dryers waste little heat in exhaust gas, and impart a high percentage of energy expended to the feed material. Scaling only becomes an issue when the scraping blades become damaged from use, or tension-based blades are unable to cut through hard deposits.

Loss of Solids (dusting/air entrainment): 5

Thin-film dryers have virtually no air entrainment, though minimal dust may be caused by scrapper blades in the lower/dryer region's dryer body. Thin-film dryers do not require substantial air flow; therefore, the air velocities, and correspondingly the air entrainment, are minimal. The dried salt materials are scraped off the drying surface as slightly wet lumps of salt, resembling wet beach sand in consistency. The salt cools and loses any free water it contained to hydration of the crystallizing salts or to evaporation. Water remaining in the salt during the scrapping process results in essentially zero dust generation.

Air Exhaust Rate: 5

Thin-film dryers require minimal air flow for efficient operation. Saturated moist air is lightly drawn away from the dryer by an exhaust fan. Air velocities, and correspondingly the air entrainment, are typically minimal. Thin-film dryers can feed exhaust air directly to the facility air handling systems after the moisture is condensed out.

Free Flowing Product: 4

Thin-film dryers do not produce a fine powdery salt like a spray dryer or a pulse dryer. Dried salt materials are typically scraped off drying the surface as slightly wet lumps of salt resembling wet beach sand in consistency. The wet solids are continuously spread and scrapped as they move through the dryer. The salt eventually cools and loses any free water it contained to hydration of the crystallizing salts or to evaporation. The salt product is free-flowing enough for the ETF process, but may leave small voids in the waste containers under some process conditions.

Ease in Maintenance: 3

Thin-film dryers are the most robust technology for variances in the feed stream. Thin-film dryers also have many moving, shearing, and abrading parts that are in contact with the contaminated feed stream. It is anticipated that most maintenance operations would involve work on contaminated components.

Ease in Operations: 4

Thin-film dryers are the most robust technology for variances in the feed stream. Given the current projected feed stream, the variations in composition are considered well within tolerance of a thin-film dryer.

Overall Applicability to this Process: 4.38

The overall applicability score is based on an un-weighted average of the individual screening criteria scores.

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APPENDIX D
EVALUATION OF 200 AREA EFFLUENT TREATMENT FACILITY SECONDARY TREATMENT TRAIN TREATMENT ALTERNATIVE

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1. Option 1: Install Supplemental Spray Dryer in Parallel with Current Dryer

Principle of Operation (10%): 2

Option 1 utilizes both spray drying and thin-film drying to meet the ETF solidification requirements. The spray drying principle of operation is onerous compared to the other drying options.

Option 1 requires more supplemental solids separation, exhaust equipment, heating equipment, and larger dryer unit than the other drying options to successfully implement the technology.

The supplemental equipment requirements are due to the exhaust gas, air entrainment, and thermal inefficiency detail in Appendix C, Section 5. The process also requires a large drying chamber compared to other equipment at ETF, to ensure the solids are dry before contacting the walls of the dryer, as to avoid build-up on the walls.

The advantages to the spray drying principle of operation are the excellent waste product and minimal maintenance requirements during ideal operation. However, the expected variations in feed and the difficulty in controlling a spray dryer in a state of ideal operation, means the advantages would seldom be realized.

Equipment Used (10%): 2

Option 1 utilizes supplemental solids separation, condenser, dedicated exhaust equipment, and heating equipment and a large spray drying unit. The equipment required for implementing a spray drying option is relatively simple and has been used for similar application; however, the required equipment is large compared to the space available at ETF and onerous compared to other options.

The drying chamber of a spray dryer capable of producing 3 kg (6.7 lb) per minute of dry sulfate salts, from a 30 wt% feed, was estimated, using correlations in *Chemical Engineer's Handbook* (Perry 1963), to be 5 m (18 ft) in diameter, and 6 m (19 ft) tall including the cone section. (Total equipment space requirement estimated to be at least 10 times the facility space requirement of the current drying system, based on contemporary examples of spray dryers for low solids feed streams.)

Solids Handling, Packaging, and Characteristics (10%): 2

Option 1 has most onerous solids handling and packaging requirements than the other drying options. Solids produced by a stray dryer contain fines that are problematic to separate from the air stream and cause dusting issues during packaging.

Option 1 produces a free-flowing solid discharged at the bottom of the spray dryer and fine solids collected by the air/solids separation equipment. Equipment required for separation of the solids from the exhaust stream and recombination with the dryer bottoms require considerable facility space and are onerous compared to the requirements of other drying options.

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Option 1 will produce a dry product that is compact and fluid. The drum filling operation will result in a dense powder with minimal voids, but dusting from the fine powders may prove problematic and be a slow operation.

Operations and Controls (5%): 2

Option 1 utilizes spray nozzles that do not tolerate variations in feed. Spray nozzles are optimized to produce fine droplets by reducing the size of the nozzle orifices and precisely controlling flow characteristics. The variations in feed composition expected in the WTP feed stream are outside the tolerance of finely-tuned spray nozzles, and the use of more tolerant spray nozzles will result in large increases in the required dryer size.

Utilities and Support Services (5%): 2

Option 1 requires substantial utilities and support services, because it utilizes a large volume of heated air to dry the sprayed particulates before they hit the walls. The air does not reach saturation and conducts a relatively small portion of its heat to the particulate before it exits the spray chamber. The utilities to support the thermal and mechanical processes of this large inefficient heated air drying system are greater than those of the other dryer options. The air requires support services including a heater, blower, solids separation system, condensation retrieval system, and a dedicated exhaust system.

Facility/Building Requirements (5%): 2

Option 1 requires more facility/building space and services than any other drying option. Option 1 is not expected to fit in the ETF process building. Option 1 will require a new ancillary building, or substantial modification of the existing connected structures to accommodate the required equipment including a dedicated exhaust system.

Compatibility and Integration with Existing Systems (5%): 2

Option 1 is the most onerous drying option to integrate into the existing system because of its control requirements, size, and the support systems it requires.

Option 1 requires an agile control system to control its numerous process parameters to feed conditions. A set of local controllers are required to maintain set points at the field equipment, which interface with a dedicated logic controller that varies the set point based on feed parameters and communicates information back to the ETF CMS.

Option 1 requires more space and support equipment than any other drying option and is similar in requirements to the cement solidification in Option 4, without any of the waste form advantages of a cement solidified waste product.

Capacity & Flexibility to Accommodate Changes in Feed Volume & Composition (10%): 1

Option 1 is the least flexible option because of the technology's low tolerance for feed variations and the size of the equipment. Spray dryers are typically highly optimized to

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reduce the size and cost of equipment. A spray dryer utilizes finely tuned sprayers and airflows that are not designed for variations in feed volume or composition, and the dryer control system can not mitigate changes in feed composition. A spray dryer can be made more tolerant to feed variations by increasing the size of the system, because an increase in tolerance is accomplished by making the sprayer and air flow rate less optimized for a specific feed, which results in a larger system requirement per volume of feed. Spray drying systems are inherently large, and slight reductions in design optimization can result in significant scaling requirements; therefore, spray dryers are only suited for consistent feed streams.

Changes Required to Implement the Alternative (5%): 2

Option 1 requires relatively major changes to implement compared to the other options. Option 1 requires more facility space and support systems than that of other drying options and is not expected to fit in the ETF process building.

Whether the Option 1 equipment is housed in a new ancillary building or existing connected structures, the dry material loading system and enclosure will need to be extended to allow drums to be filled below the new dryer. Both dryers are best suited for gravity-assisted vertical discharge.

Option 1 will require significant new training and procedures it implement because its control characteristics and differences from the current ETF solidification process. The exhaust characteristic may also significantly change facility emissions and corresponding regulatory and safety documents.

Installed Cost (5%): 3

Option 1 utilizes numerous large pieces of equipment, but there are few moving parts and the equipment is simple and cheap, consisting mostly of sheet-metal tubing and cone-shaped chambers. The required control system is estimated to be as expensive as the other hardware combined. The heating equipment required is the largest and most expensive of the three drying options.

Cost of Operation (5%): 2

Option 1 has a relatively high cost of operation compared to the other options. Option 1 is relatively energy inefficient, as described by Appendix C, Section 5, but it also has the largest volume of entrained fine particulates among the drying options, and therefore has the largest fine filter costs of the three dryer options.

Reliability, Availability, and Maintainability (10%): 2

Option 1 has relatively low reliability, availability, and maintainability compared to the other options. Low tolerance for varying feed streams is expected to cause operational problems that will result in maintenance evolutions. Air/solids separations for Option 1 require more maintenance than other options because of the large volume of air and entrained solids.

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Hazards and Safety Considerations (5%): 4

Option 1 has hazards and safety issues similar to most drying technologies, including high temperatures, pressurized systems, exhaust gas streams, and maintenance requirements that include contact handling of radioactive and hazardous material.

Thermo-baric hazards associated with spray dryers are relatively low, because Option 1 utilizes relatively low heat, and very low pressures. Exhaust hazards are slightly higher than thin-film or pulse drying because more solids are entrained, requiring more filter media maintenance. Dryer maintenance involving contact handling of contaminated parts is relatively low because spray dryers have few contaminated moving parts, and spray nozzles can be changed-out externally with minimal contact.

Compliance with Applicable Requirements (10%): 4

Option 1 is a suitable technology to comply with applicable requirements, including waste form, and waste acceptance criteria. However spray drying technology is not suitable to compensate operationally for the expected variation in feed composition. Feed composition that could not be compensated for operationally would require maintenance to remove fouling and build-up. Variations in feed may cause unscheduled maintenance in excess of the requirements for acceptable reliability, availability, and maintainability.

Overall: 2.25

Option 1 is more onerous than the other drying options because of its intolerance for varying feed streams, production of fine solids, size, and support requirements. The solids handling requirements are closer to cement solidification in Option 4 than the current ETF system, but results in a non-stabilized waste form.

Option 1 is a viable drying option, but it fails in comparison to the thin-film technology in Option 3 in every category.

2. Option 2 Install Supplemental Pulse Dryer in Parallel with Current Dryer

Principle of Operation (10%): 3

Option 2 utilizes both pulse drying and thin-film drying to accomplish the ETF solidification requirements. The pulse drying principle of operation may be problematic because of supplemental solids separation and exhaust equipment required to successfully implement the technology. The supplemental equipment requirements are due to the exhaust gas and air entrainment issues detailed in Section 4.0 of Appendix C.

The expected variation in feed composition may be problematic for the pulse dryer. Variations in the feed composition will affect the pattern and moisture content of the material suspended in the pulse. It the material is too wet or sticky when it makes contact with the internal surfaces of the pulse dryer, it may cause fouling or significant build-up.

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The pulse drying principle of operation is possibly the most efficient method for solidifying a liquid stream into a dry free-flowing solid, because it also uses energy from the heating fuel to produce the air flow and to atomize the liquid. Pulse drying also produces an excellent waste product and requires minimal maintenance during ideal operation. However the pulse drying is a new technology and has less industrial history to predict potential problems. The expected variation in feed composition may also prove problematic.

Equipment Used (10%): 2

Option 2 utilizes supplemental solids separation, condenser, dedicated exhaust equipment, and pulse drying units approximately three times the size of the current ETF thin-film dryer oriented horizontally. Implementing the pulse drying option would require solids separation equipment and a dedicated exhaust system that a thin-film drying system would not. However the solids separation equipment and the dedicated exhaust system would be much smaller (e.g., 50 to 25% of scale) than that required to implement spray drying.

The dryer body of a pulse dryer capable of drying 3 kg (6.7 lb) per minute of dry material, from a 30 wt% feed, was estimated, by the manufacturer, to be 3 m (10 ft) in diameter, and 10 m (30 ft) long. (Total equipment space requirement estimated to be at least 6 times the facility space requirement of the current dry system, based on contemporary examples of spray dryer for low solids feed streams.)

Option 2 would likely require noise isolation to maintain noise levels similar to those currently produced on the ETF process floor.

Solids Handling, Packaging, and Characteristics (10%): 3

Option 2 has more onerous solids handling and packaging requirements than Option 3. Solids produced by a pulse dryer contain fines that are problematic to separate from the air stream and cause dusting issues during packaging.

Option 2 produces a free-flowing solid discharged at the outlet of the pulse dryer and fine solids collected by the air/solids separation equipment. Equipment required for separation of the solids from the exhaust stream and recombination with the dryer bottoms require considerable facility space and are onerous compared to the requirements of thin-film drying (Option 3).

Option 2 will produce a dry product that is compact and fluid. The drum filling operation will result in a dense powder with minimal voids, but dusting from the fine powders may prove to be a problematic and slow operation.

Operations and Controls (5%): 2

Option 2 is a relatively new technology, but it has not been employed using computerized logic controllers. It is unknown whether advanced control systems can significantly increase pulse drying technology tolerance to varying feed stream compositions.

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Pulse dryers use spray nozzles that tolerate a greater degree in feed variation than the highly optimized spray nozzles in spray dryers, because pulse dryers use a sonic pulse to achieve optimum atomization and not sprayer design.

Spray nozzles are optimized to produce fine droplets by reducing the size of the nozzle orifices and precisely controlling flow characteristics. The variations in feed composition expected in the WTP feed stream are outside the tolerance of finely-tuned spray nozzles. The use of more tolerant spray nozzles will result in large increases in the required dryer size.

Utilities and Support Services (5%): 3

Option 2 requires substantial utilities and support services, because it utilizes air for heat transfer to dry the sprayed particulates. The air does not reach saturation and conducts a relatively small portion of its heat to the particulate before it exits the spray chamber. The utilities to support the thermal and mechanical processes are greater than those of the dryer options, which are heated surfaces for heat transfer. The air requires support services including a solids separation system, condensation retrieval system, and a dedicated exhaust system.

Pulse dryers do not require air heaters or fan systems, because they use the pulse from the heating fuel to propel the air and atomize the liquid feed. However pulse dryers are fuel-fired and required systems to support fuel storage and either a fixed fuel service or re-supply service.

Facility/Building Requirements (5%): 3

Option 2 requires more facility/building space and services than thin-film drying (Option 3). Option 2 is not expected to fit in the ETF process building because of its size and horizontal orientation. Option 2 will require a new ancillary building, or substantial modification of the existing connected structures to accommodate the required equipment including a dedicated exhaust system.

Option 2 may require noise isolation. The pulse drying system is equipped with a muffler system; however, supplemental isolation will be required to maintain current facility noise levels.

Compatibility and Integration with Existing Systems (5%): 3

Option 2 is a relatively moderate drying option to integrate into the existing system. Integration of Option 2 is made difficult by its relatively large dryer, onerous exhaust system, and higher noise levels. However Option 1 requires a larger dryer and more onerous exhaust system.

Option 2 will require a fuel source since it can not be electrically heated, and an upgraded control system to communicate with the ETF CMS. Option 2 requires more space and support equipment than Option 3, without offering any significant advantages.

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Capacity & Flexibility to Accommodate Changes in Feed Volume & Composition (10%): 4

Option 2 is relatively flexible because of its brute force atomization and the high temperature of the pulsed drying gases. Pulse dryers are typically tolerant to variations in feed volume or composition. However compared to thin-film drying (Option 3) it has significantly less operational history with similar wastes and has not been tested with ETF brine compositions, which limits the predictability of its performance.

Changes Required to Implement the Alternative (5%): 3

Option 2 requires relatively moderate changes to implement compared to the other options. Option 2 requires more facility space and support systems than is required by Option 3, and it is unknown if it will fit in the ETF process building.

Option 2 utilizes an auger system to move dry material and does not require vertical discharge, therefore the equipment may be housed in a new ancillary building, or existing connected structures, and transported into the existing dry material packaging system.

Option 2 will require significant new training and procedures to implement because of its control characteristics and differences from the current ETF solidification process. The exhaust characteristics may also significantly change facility emissions and corresponding regulatory and safety documents.

Installed Cost (5%): 3

Option 2 utilizes numerous large pieces of equipment, but there are few moving parts and the equipment is simple and cheap, consisting mostly of exhaust systems made of sheet-metal tubing and cone-shaped chambers. Option 2 does not require supplemental heating equipment.

Cost of Operation (5%): 4

Option 2 has a relatively low cost of operation compared to the other options. Option 2 is relatively energy efficient, as described by Section 4.0 of Appendix C, but it also has a large volume of entrained fine particulates, and therefore has the large fine filter cost.

Reliability, Availability, and Maintainability (10%): 4

Option 2 has relatively high reliability, availability and maintainability compare to the other options. However compared to thin-film drying (Option 3) it has significantly less operational history with similar wastes and has not been tested with ETF brine compositions that may cause unscheduled maintenance in excess of the requirements for acceptable reliability, availability and maintainability.

Hazards and Safety Considerations (5%): 3

Option 2 has hazards and safety issues similar to most drying technologies, including high temperatures, pressurized systems, exhaust gas streams, and maintenance requirements that include contact handling of radioactive and hazardous material.

Thermo-baric hazards associated with pulse dryers are relatively moderate, because Option 2 utilizes relatively high heat, but for a short time in a well confined chamber of the system. Exhaust hazards are slightly higher than for the thin-film dryer because more solids are entrained, requiring more filter media maintenance. Dryer maintenance involving contact handling of contaminated parts is relatively low because spray dryers have no contaminated moving part, and spray nozzles can be changed-out externally with minimal contact.

Option 2 may have a perception of hazard due to the small fuel air exposition that causes the drying pulse (much like a diesel engine), and this perception may be difficult to mitigate. However Option 2 is not considered to be more hazardous or less safe than other drying methods.

Compliance with Applicable Requirements (10%): 4

Option 2 is a suitable technology to comply with applicable requirements, including waste form, and waste acceptance criteria. However compared to thin-film drying (Option 3) it has significantly less operational history with similar wastes and has not been tested with ETF brine compositions that may cause unscheduled maintenance in excess of the requirements for acceptable reliability, availability and maintainability.

Overall: 3.2

Option 2 is capable and robust drying option, however it is more onerous to employ than Option 3 because of its production of fine solids, size, noise, and exhaust system requirements. Option 2 also has significantly less operational history with similar wastes and has not been tested with ETF brine compositions.

3. Option 3: Install Supplemental Thin-Film in Parallel with Current Dryer

Principle of Operation (10%): 5

Option 3 utilizes two thin-film dryers optimized for different feed streams to meet the ETF solidification requirements. The thin-film drying principle of operation is robust and tolerant compared to the other drying options.

Option 3 requires the least supplemental solids separation, exhaust equipment, heating equipment, and a smaller dryer unit than the other drying options to successfully implement.

Option 3 requires such minimal supplemental equipment requirements because of its low exhaust gas volume, minimal air entrainment, and thermal efficiency detail in Appendix C, Section 7. The additional thin-film dryer required is significantly smaller than the additional dryers required by the other options.

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Equipment Used (10%): 5

Option 3 requires the least support equipment of any option and requires the smallest drying unit. Option 3 utilizes heating equipment, condenser unit, and a moderately sized thin-film drying unit.

The current condenser and exhaust system may be sufficient to support a new larger thin-film dryer (system loads would have to be further evaluated to make that determination).

The equipment required for implementing a supplemental thin-film dryer are similar to those currently being use at ETF. Process flexibility would be enhanced by configuring the dryers with different blades, each optimized for a specific stream (e.g., a wider more ridged blade in the large dryer for sodium sulfate/ammonium sulfate, and a smaller tensioned-scrapping wiper for the small dryer for harder solids).

The drying chamber of a thin-film dryer capable of producing 3 kg/min (6.7 lb/min) of dry sulfate salts, from a 30 wt% feed, was estimated to be twice the size of the current EFT thin-film dryer body. The dryer skid for the supplemental dryer would be similar to the current ETF dryer skid, and include the dryer motor, condenser, discharge unit, etc. The new skid would have a footprint approximately the same size are the existing skid, but would be 2 to 3 m (5 to 10 ft) taller (Scully and Horton 2004).

Solids Handling, Packaging, and Characteristics (10%): 3

Option 3 has the least onerous solids handling and packaging requirements of the options. Virtually no solids are entrained in the exhaust gas, eliminating the need for supplemental solids separation and reducing the use of filter media. The solids exiting the dryer contain a small amount of water that almost eliminates dust production. The remaining water is rapidly evaporated and converted to hydrates in the container, yielding a dry solid with no free-water. However the wetter solids do not pack as tightly as the products from the other dryer. Once they consume the free water there are small void that remain, slightly reducing waste density and increasing waste volume.

The vertical counter-current design on the thin-film dryer in Option 3 ensures any dust created at bottom of the system, near the solid discharge, which is entrained in the air stream travels back up through the humid upper portion of the drying chamber and is scrubbed back into the liquid phase.

Operations and Controls (5%): 4

Option 3 utilizes thin-film dryers that are the most tolerant drying technology for variations in feed. The other drying technologies, with the exception of drum drying, can not tolerate solids build-up on internal surfaces because they have no mechanism to remove the build-up, and as a result they are intolerant to variations in feed, which can cause solids to build-up on internal surfaces. The ability of a thin-film dryer to remove build-up, regardless of its feed origin, makes it exceptionally tolerant to feed variation. Different blade and wiper designs can be optimized for different waste streams, include streams that produce sticky or exceptionally hard salts.

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Thin-film dryers use brute force control build-up, and do not rely on precise sprayers or fluidizing air flows to control drying and prevent build-up. Therefore thin-film dryers are relatively simple to operate and control, unless the scrappers/wipers are unsuited for the feed stream, and then uncontrolled build-up typically causes failure and requires maintenance.

Utilities and Support Services (5%): 4

Option 3 requires the least utilities and support services of the options, because option 3 uses heat efficiently, produces virtually no air entrained solids, and has a low exhaust gas volume.

Option 3 is not expected to require supplemental solids separation of exhaust equipment. However an additional dedicated condenser may be required.

Facility/Building Requirements (5%): 5

Option 3 requires less facility/building space and services than any other option. Option 3 is expected to fit in the ETF process building with no substantial modification.

Compatibility and Integration with Existing Systems (5%): 5

Option 3 is the most compatible option to integrate into the existing system because of its size and limited support system requirement.

Option 3 requires a control system that is virtually identical to the system current controlling the ETF thin-film dryer. Option 3 requires less space and support equipment that any other option and because of the small scaling factor, the supplemental dryer is similar in size and requirements to the existing dryer.

Capacity & Flexibility to Accommodate Changes in Feed Volume & Composition (10%): 4

Option 3 is the most flexible option due to the technology's high tolerance for feed variations and the robust design of the equipment. Thin-film dryers typically do not require tight tolerances on feed stream. Even moderate deviations in composition and total dissolved solids concentration are compensated at the dryer motor where drive current in moderated to compensate for changes in motor load. Fundamental changes in the feed stream, such as the production of a much harder or stickier solid can cause stresses and shear forces that are outside the dryers design. Fundamental changes in feed stream should be accommodated by changing the internal configuration of the dry.

Changes Required to Implement the Alternative (5%): 4

Option 3 requires the least changes to implement of any option. Option 3 requires less facility space and support systems than any other option and is expected to fit in the ETF process building.

A skid based version of the supplemental thin-film drying system in Option 3, would be similar in size to the existing ETF thin-film dryer skid, and have a similar gravity assisted

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vertical discharge. The existing drum loading system and enclosure could be extended to allow drums to be filled below the new dryer.

Option 3 will require minor additional training and procedures changes to implement because its similarity to the current ETF solidification process. Changes to the facility emissions and corresponding regulatory and safety documents and limited because Option 3 does not require supplemental air filtration or a dedicated exhaust system and is similar to the existing system.

Installed Cost (5%): 3

Option 3 has a relatively low installation cost compared to the other options. While thin-film dryers are relatively expensive to fabricate and are complicated, they require virtually no exhaust support equipment beyond a small condenser. Systems such as the supplemental system required in Option 3 are typically skid based units containing all necessary components except the heating/steam system.

A budgetary cost estimate for Option 3 was provided by the vendor of the existing ETF Thin-Film Dryer to meet the projected ETF boundary case influent. A skid-based system including condenser and lower drum mating assembly was estimated at $1.5 million +/- 30% (Scully and Horton 2004).

Cost of Operation (5%): 4

Option 3 has a relatively low cost of operation compared to the other options. Option 3 is relatively energy efficient, as described by Section 7.0 of Appendix C, and has the smallest volume of entrained fine particulates among the drying options, and requires no supplemental solids separation or filtration.

Reliability, Availability, and Maintainability (10%): 4

Option 3 has relatively high reliability, availability and maintainability compare to the other options. High tolerance for varying feed streams is expected to mitigate operational problems that can result in maintenance evolutions. Option 3 requires less maintenance than other options because of the minimal volume of air and entrained solids. However, thin-film dryers have large moving parts in contact with hazardous process materials that require maintenance, which typically require major disassembly and increase worker exposure.

Hazards and Safety Considerations (5%): 5

Option 3 has hazards and safety issues similar to most drying technologies, including high temperatures, pressurized systems, exhaust gas streams, and maintenance requirements that include contact handling of radioactive and hazardous material.

Thermo-baric hazards associated with thin-film dryers are relatively low, because Option 3 utilizes relatively low heat, and very low pressures. Exhaust hazards are lower than that of spray dryers or pulse drying because less solids are entrained, requiring less filter media

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maintenance. Dryer maintenance involving contact handling of contaminated parts is relatively high because thin-film dryers have contaminated moving parts.

Compliance with Applicable Requirements (10%): 5

Option 3 is a suitable technology to comply with applicable requirements, including waste form, and waste acceptance criteria. Thin-film drying is the most suited drying technology to compensate for the expected variation in feed composition. Thin-film drying has a proven history of compliance with the ETF requirements.

Overall: 4.4

Option 3 is the most capable and robust drying option, requires the least facility space, and produces less fine solids, noise, and exhaust than any other option. Option 3 also has significantly more operational history with similar wastes and has proven performance with ETF brine compositions.

4. Option 4: Install Supplemental Cement Solidification in Parallel with Current Dryer

Principle of Operation (10%): 5

Option 4 utilizes both cement solidification and thin-film drying to accomplish the ETF solidification requirements. The cement solidification principle of operation may be unnecessarily onerous if the solidification requirement is a dry material; however, if a stabilized waste form or shielding is required, then cement solidification is the least onerous process to accomplish those goals.

The cement solidification principle of operation is the most efficient method for stabilizing a liquid brine stream into a solid waste form, because it uses inexpensive materials, no heat, relatively little power and labor. Cement solidification also produces an excellent waste product and requires minimal maintenance during ideal operation; however, the cement solidification technology has been problematic to implement on a large scale at the Hanford Site, because of comparisons to the Hanford Grout Project waste form and some comparisons to glass solidification.

Equipment Used (10%): 5

Option 4 utilizes a cement solidification process, which would be tailored to the solidification, transportation and disposal requirements of the projected WTP brine stream. The cast stone process is an example of a cement solidification process that could be tailored to meet the ETF requirements, although it is anticipated that cast stone formulation would be used in conjunction with a smaller mixer and container than the cast stone project required.

Numerous cement solidification technologies exist, and there are dozens that are tailored to waste streams similar to the projected WTP brine stream. The cast stone process is used as a cement solidification example because of similarity of its waste stream, and the recent testing and demonstration results achieved with Hanford Site brine tank waste.

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Typically a cement solidification system of the size required utilizes batch ribbon-type mixers sized for one batch to fill one container. The mixer receives batches of concentrated brine waste storage tanks and dry reagents from the dry reagent receipt, storage, and metering system.

Dry reagents are gravity fed to the mixer from their respective weigh bins during cast stone mixing. Mixing requires approximately 15 minutes per batch, after which the mixer gravity-drains the stabilized waste into an empty waste container staged in place by a containerization process.

The mixer operates continuously during the shift, including between batches. At the end of the shift, the mixer is rinsed using approximately 10 to 100 L (2.6 to 26 gal) of flush water. The resulting rinse is emptied into a dedicated container for subsequent disposal or recycled back to the process.

Mixer overhead filters are prefilters that collect dust generated during dry reagent addition to minimize particulate load on the vessel vent system, and then routed to the plant HEPA filtration system before discharge into the atmosphere.

The concentrated low-activity waste solution and the various reagents are thoroughly mixed in the batch ribbon mixer to provide a homogenous consistency and chemical stabilization. After mixing is completed, the final cast stone product is gravity-fed into a 10.5 m^3 (300 ft^3) container on a batch basis. Both the mixer and container are sized for the same batch volume to mitigate overfilling of containers.

After the cast stone product has been emptied from the mixer into a container, the container is closed by applying a lid over the opening, radiologically surveyed.

Solids Handling, Packaging, and Characteristics (10%): 5

Option 4 may require more solids handling equipment than any other option, but almost of it is for non-radioactive, non-hazardous, dry reagents such as portland cement. Option 4 receives a liquid brine feed stream. The mixed waste feed stream only becomes a solid after the cement sets in the waste container, and therefore system produces less airborne contamination.

Cement solidification systems typically have large outdoor dry reagent component and smaller indoor components that contain hazardous, radioactive of mixed wastes. Typically outdoor silos receive dry reagents (individually or pre-mixed) from a vendor.
A vendor-supplied pulse transfer system moves dry reagents in slugs to a feed hopper that meters the correct amount of dry reagents into the mixer using a loss-of-weight feed system. The transfers and system monitoring are automated and only require operator interface if the systems encounters a problem it can not automatically correct.

Operations and Controls (5%): 4

Option 4 requires a steady but relatively small commitment of personnel to support dry material receipt and attend to solids handling issues identified by the control system.

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Vendors typically supply dry reagent but the unloading requires supervision. The automated solids handling systems are designed to identify problems (typically clogging) that are subsequently mitigated by an operator manually tamping a clogged transfer line.

Utilities and Support Services (5%): 2

Option 4 has relatively modest power requirements compared to the mixer options, but requires significant dry material handling utilities and support. The cement solidification mixer units are typically robust and powerful, typically hundreds of horse power. The power required to support Option 4 is within the range of the dryer options. The dry material handling system will require an air compressor and pneumatic systems for material transfer. Dust control and exhaust systems will be required for both the non-contaminated dry material handling system, and the contaminated mixer exhaust.

Facility/Building Requirements (5%): 3

Option 4 is more suitably housed off the main process floor because of the noise and associated exterior dry material handling systems. Option 4 will require a new ancillary building, or substantial modification of the existing connected structures to accommodate the required equipment including a dedicated exhaust system.

Compatibility and Integration with Existing Systems (5%): 4

Option 4 is the compatible with the existing ETF systems; however it will not utilize many of the STT systems down stream of the evaporator. Option 4 can accept nitrate salts and high pH feed streams, therefore no pH adjustment is required for the projected WTP brine feed stream. Option 4 will require a dedicated containerizing system. Option 4 would also require dedicated container logistics if the container size selected for Option 4 is not a 55-gallon drum.

Option 4 would require several new systems housed outside the process floor and would require integration into the ETF control system including; an exterior dry reagent receiving and storage facility, mixer, container loading system, and a ventilation system.

Option 4 would require no modifications to the existing dryer system or the container loading system; therefore, the existing dry process would require no re-testing or qualification and could continue to operate during the installation, testing and start-up of the cement solidification process.

Capacity & Flexibility to Accommodate Changes in Feed Volume & Composition (10%): 5

Option 4 can be automated to adjust to feed density and therefore is flexible to variations in feed rate and feed total dissolved solids concentration; however, because cast stone and other cement solidifications are chemical reactions, variation in the composition of the some specific constituents can be problematic. Therefore, the capacity and flexibility of Option 4 cannot be satisfactorily defined until specific dry reagent formulas are evaluated against the full range of waste constituents.

Changes Required to Implement the Alternative (5%): 3

Option 4 requires relatively major changes to implement compared to the other options. Option 4 requires a new exterior enclosure for the mixer and container loading equipment, and a dry material receipt, storage and transfer system. However, Option 4 would require no modifications to the existing dryer system or the container loading system, therefore they could continue to operate during the installation, testing and start-up of the cement solidification process.

Option 4 will require significant new training and procedures to implement because of its differences from the current ETF solidification process. The exhaust characteristic may also significantly change facility emissions and corresponding regulatory and safety documents.

Logistics for the dry reagent material and container will have to be developed and supported by ETF staff during operation. The majority of operator interface with Option 4 is in support of container logistics.

Installed Cost (5%): 4

Option 4 would most likely have a low installation cost compared to the other options, because there are cement solidification demonstration facilities that could be adapted for use at ETF. Besides cost, the advantages of using a proven demonstration facility are significant. Some of the existing demonstration facilities have successfully solidified and containerized thousands of tons of cement solidified mixed waste brine. The systems and procedures have been demonstrated that would expedite the process and minimize design and testing of a new system.

Option 4 would most likely utilize an existing demonstration cement solidification system that has completed its mission. Several cement solidification systems are available that meet the projected process requirements and have a proven record of stabilization operations for similar wastes. The purchase cost of these systems has previously been estimated at $0 to $200,000, and the cost of relocation, reassembly, and revalidation is relatively low due to the modular construction of the systems. The rough order of magnitude installed cost is $1.1 million which includes capability to unload tankers directly to the STT.

Cost of Operation (5%): 4

Option 4 has a relatively low cost of operation compared to the other options. Option 4 is relatively energy efficient, requiring less energy per unit waste processed than the drying alternatives. Option 4 has a small volume of entrained contaminated particulates that are typically filtered, by an expanding back-flushable filter, back into the mixing unit. Minimal solids remain entrained in the exhaust down stream from the back-flushable filter and the exhaust. Therefore, there is expected to be no need for supplemental solids separation or filtration, which require maintenance. The exhaust from the back-flushable filter may be treated similar to the existing thin-film dryer exhaust, and processed by existing ETF systems.

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Reliability, Availability, and Maintainability (10%): 4

Option 4 has relatively high reliability, availability, and maintainability compared to the other options. The cement solidification mixer units are typically robust, powerful, and reliable. The automated solids handling systems are designed to operate autonomously and identify problems (typically clogging). Operator or maintenance interface is required only when problems are identified. Typically operators are required to manually tamp clogged transfer lines to free an impediment a few times a month.

Option 4 can be tolerate widely varying feed streams, depending on the waste form requirements. However, if the cement formulation is highly optimized to allow the maximum waste loading for a specific feed, using an unsuited waste stream may result in waste form that fails to meet some of the requirements, such as leaching index.

Hazards and Safety Considerations (5%): 4

Option 4 has hazards and safety issues similar to other mixed waste solidification processes, including pressurized waste transfer system systems, contaminated exhaust gas streams, and maintenance requirements that include contact handling of radioactive and hazardous material.

Thermo-baric hazards associated with cement solidification are less than those associated with drying technologies, because temperatures are kept below 158 °F (70 °C) and pressure is maintained at a slight negative (typically drawing 1.5 cm [0.5 in.] of water gauge on the mixer body and related systems).

Exhaust hazards are lower than those of most dryers because the only contaminated exhaust is discharged from the mixer body as brine and dry reagent fills the void. The contaminated exhaust is typically filtered by a small robust automatically back flushing filter internal to the mixer unit. Therefore little or no supplemental treatment is required for contaminated exhaust. It is expected that the exhaust gas from a mixer unit could be processed similarly to the exhaust of the current thin-film dryer, and similarly require no supplemental filter media maintenance. Mixer maintenance involving contact handling of contaminated parts is relatively rare because of lack of filter media replacements and the robust design of the mixers.

Compliance with Applicable Requirements (10%): 5

The solidification requirements are not defined beyond a no-free-water requirement. Option 4 is a suitable technology to complying with more stringent waste form requirements and waste acceptance criteria than are currently required. Option 4 is an excessively aggressive solidification process to meet the no-free-water requirement. However, if more stringent waste form requirements and waste acceptance criteria are place on ETF waste originating from the WTP brine stream, they would likely include leaching and durability requirements that could be met by Option 4. Option 4 drying has a proven history of compliance with the brine streams similar to the projected ETF feed streams.

Overall: 4.3

Option 4 is a capable, robust and simple solidification option. Option 4 drying has a proven history of compliance with the brine streams similar to the projected ETF feed streams. However, Option 4 is an excessively aggressive solidification process to meet the no-free-water requirement. If more stringent waste form requirements and waste acceptance criteria are place on ETF waste originating from the WTP brine stream, Option 4 is recommended as the solidification method.

References

Perry, J. H., 1963, *Chemical Engineers' Handbook*, 4th edition, McGraw-Hill Book Company, New York, New York.

Skully, R. and J. Horton, 2004, "Project file, e-mails, and note from phone consultations," Process Engineering, LCI Corp.

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APPENDIX E
CAST STONE PROCESS – WASTE PRODUCT
PERFORMANCE REQUIREMENTS

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Table E.1. Waste Product Requirements for the Containerized Cast Stone System (2 Sheets)

Characteristic	Requirement

Strength	• Compressive strength: ≥ 3.45 E+06 Pa per ASTM C39/C39M-99, or equivalent
	• Resistant to thermal, radiation, biodegradation, and immersion degradation per NRC (1995)
	• Greater than 75% of initial compressive strength after:
	  – ASTM B553-79, or equivalent, 30 thermal cycles between 60 °C and -40 °C
	  – Exposure to 1.0 E+08 rad or maximum self-irradiation, whichever is greater
	  – No evidence of culture growth per ASTM G21-96 and ASTM G22-76 (R1996)
	  – ANSI/ANS-16.1 immersion for 90 days

Leachability	• 40 CFR 268 • SW-846 Method 1311 leachability testing • ANSI/ANS-16.1 sodium leachability index >6.0 when tested 90 days in deionized water • No detectable free liquids per ANSI/ANS-55.1 or SW-846 Method 9095
Other	• Waste shall not contain or be capable of generating quantities of explosive (e.g., hydrogen) or toxic gases, vapors, or fumes harmful to persons handling waste • HNF-EP-0063 hydrogen gas generation criteria • No return streams to the source tanks • Minimize waste volume within constraints of other specifications • Maximum allowable 70 °C curing temperature (to preclude damage to product) • Volume reduction on curing: <2% • Radionuclide concentration: less than Class C limits per 10 CFR 61.55 and NRC (1995) • Not pyrophoric or explosive, readily capable of detonation, or readily capable of explosive decomposition or reaction (including reaction with water); waste form and any optional filler material shall not be ignitable or reactive per WAC 173-303-090(5) and WAC 173-303-090(7)

Table E.1. Waste Product Requirements for the Containerized Cast Stone System (2 Sheets)

10 CFR 61.55, "Licensing Requirements for Land Disposal of Radioactive Waste," *Code of Federal Regulations*, as amended.

40 CFR 268, "Land Disposal Restrictions," *Code of Federal Regulations*, as amended.

ANSI/ANS-16.1, 1986, *Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a Short Term Test Procedure*, American National Standards Institute/American Nuclear Society, La Grange Park, Illinois.

ANSI/ANS-55.1, 1992, *Solid Radioactive Waste Processing System for Light-Water-Reactor Plants, Appendix B, Testing for Free Liquids in Solidified Matrices*, American National Standards Institute/American Nuclear Society, La Grange Park, Illinois.

ASTM B553-79, 1979, *Standard Test Method for Thermocycling of Electroplated Plastics*, American Society for Testing and Materials, Easton, Maryland.

ASTM C39/C39M-99, 1999, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*, American Society for Testing and Materials, Easton, Maryland.

ASTM G21-96, 1999, *Standard Practice of Determining Resistance of Synthetic Polymeric Materials to Fungi*, American Society for Testing and Materials, Easton, Maryland.

ASTM G22-76 (R1996), 1976, *Standard Practice for Determining Resistance of Plastics to Bacteria*, American Society for Testing and Materials, Easton, Maryland.

HNF-EP-0063, 1998, *Hanford Site Solid Waste Acceptance Criteria*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

NRC, 1995, *Branch Technical Position on Concentration Averaging and Encapsulation*, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C.

SW-846, 2002, "Method 1311 – Toxicity Characteristic Leaching Procedure," *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

SW-846, 2002, "Method 9095 – Paint Filter Liquids Test," *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.
  090(5), "Characteristic of ignitability."
  090(7), "Characteristic of reactivity."